Aeroplane Maintenance and Operation Series, Volume 18

CARBURETTORS

(PART 2)

AEROPLANE MAINTENANCE AND OPERATION SERIES

Compiled under the General Editorship of E. MOLLOY

VOL. NO.

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Aeroplane Maintenance and Operation Series, Volume 18

CARBURETTORS

(PART 2)

DEALING WITH ZENITH, ROLLS ROYCE, AND STROMBERG CARBURETTORS, WITH SPECIAL NOTES ON BOOST PRESSURE CONTROL

General Editor

E. MOLLOY

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E. W. KNOTT, M.I.A.E., M.S.A.E.

COMPILED BY A PANEL OF EXPERTS

WITH ONE HUNDRED AND SIX ILLUSTRATIONS

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PREFACE

WHILST, in broad outline, the function of the aero-engine carburettor may be described in a few words, namely, to vaporise the engine fuel and to supply it to the engine mixed with air in accurate proportions to ensure efficient combustion in the engine cylinders—in actual practice, so many factors have to be taken account of that the modern aero-engine carburettor has become a highly specialised piece of work.

The present book deals with three important ranges, namely, the Zenith, the Rolls-Royce "Kestrel," and the Stromberg. In the latter case, several different types have been described in detail. Special attention has been devoted to this, the Stromberg, range, in view of the fact that these carburettors are very largely used in American aircraft.

The general plan of treatment followed in each case has been to describe broadly the principles of construction of the particular model dealt with, and then to give detailed information concerning dismantling, adjustment, and reassembly. This treatment has been found in practice to give the best results from the point of view of the ground engineer, aircraftsman, and maintenance engineer.

In addition to the above, the present book contains two other important sections. Particular attention is drawn to the section beginning on page 33, and entitled "Notes on Boost Pressure Control and Mixture Strength."

In view of the very wide employment of "blown" or supercharged engines, this subject of boost pressure control is of outstanding importance to those responsible for obtaining the most efficient performance from aero engines in present-day use.

The other section which we have in mind is that beginning on page 69. It is entitled "The Cambridge Exhaust Gas Analyser." This useful adjunct to the efficient running of an engine may be used either with manually operated mixture control or with automatic mixture control. It incorporates an electrical circuit of the Wheatstone Bridge type, and provides the pilot of an aeroplane with a visual indication of the suitability or otherwise of the fuel and air mixture which is being supplied to the engine. Full details will be found in the article referred to.

We take this opportunity of placing upon record our indebtedness to the following manufacturers, who have assisted us in the compilation of this book :

The Zenith Electric Company, Ltd.
Rolls-Royce Limited.
The Bendix-Stromberg Carburettor Company.
Cambridge Instrument Co. Ltd.

It is hoped that the collection of this varied and up-to-date information on the subject of aircraft carburettors and carburation, and other associated problems, will prove to be of wide interest to those engaged in the aircraft industry and of the greatest practical utility to ground engineers and others concerned in the maintenance of aero engines.

E. W. K.
E. M.

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CARBURETTORS

ZENITH TYPE 40 FAIH CARBURETTOR AS FITTED TO DE HAVILLAND "MOTH MINOR"

THE De Havilland " Moth Minor " engine is carburated by a down-draught carburettor of 40 mm. bore. It is fitted to the engine by a square flange having a four-bolt fixing. The carburettor is of particularly straightforward design. Apart from the arrangement incorporated for altitude control of mixture and special modifications demanded by aero requirements, it will be seen that the design follows very closely that of normal car-engine practice.

Float Chamber

Reference to section drawing Fig. 1 will show that petrol feed to the carburettor is by means of the banjo union 3. A plug 2 is carried through this union to the head of the needle seating assembly 1.

If petrol in the float chamber is standing at its predetermined level, then the float will hold the needle 4 tight against its seating, and prevent the entry of more fuel. The float is of orthodox design (Fig. 2). It is a brass petrol-tight cylinder with an arm 26 that pivots on a spindle at 27. The needle 4 " rides " on this float arm. The float and its arm fall as the petrol in the chamber drops below its highest level. As a result, the needle 4 will, by reason of its own weight and by the fuel pressure being exerted upon it, follow the float arm. In this manner the needle leaves its seating, and petrol will flow into the float chamber through the seating drillings. It will continue to do so until a predetermined maximum level is attained. By this time the float and arm will have once more lifted the needle on to its seating and prevented the entry of more petrol.

This system of level control can be violated by means of the " tickler " (Fig. 2) 29, which is operated by raising the lever 30. Working on the pivot 31, the tickler lever depresses the plunger 29.

Acting against the spring 28, the plunger strikes the float 5 and forces it below the height at which it is suspended in the fuel by reason of its own buoyancy. The needle will again leave its seating and addi-

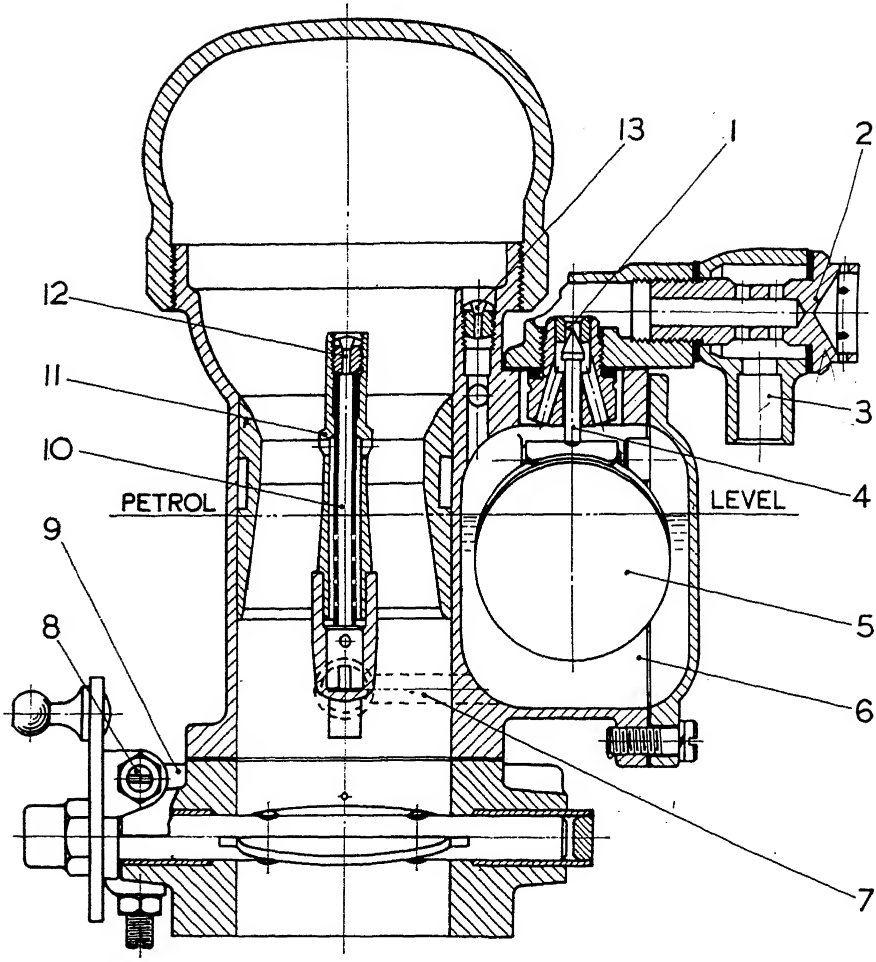


Fig. 1.—Sectional diagram of Zenith type 40 FAIH carburettor

tional fuel will enter the float chamber until the tickler arm is released and the spring 28 forces the plunger 29 upwards clear of the float. The normal functioning of the float mechanism is then resumed.

Adjustments

The correct operation of fuel-level control in the float chamber depends upon :

(*a*) The buoyancy of the float.
(*b*) The effective sealing of the seating by the needle.
(*c*) The maintenance of anticipated fuel pressure.

(*a*) **The Float**

This part must remain absolutely petrol tight at all times. If it becomes punctured and consequently petrol-logged, high level or even flooding will result.

To inspect the float, it is necessary to remove the side of the chamber by taking out the five retaining screws (Fig. 4). The float is then free to be slid off the pivot pin 27. Shaking the float usually reveals readily the presence of petrol inside. The quickest way of finding the puncture is to insert the float into boiling water. Air inside will expand and force its way out through the puncture. The resultant air bubbles in the hot water will reveal the position of the puncture. An emergency repair may be made with solder, but a new float should be procured at the earliest opportunity. If the float is soldered, its weight is increased, and the tendency will be for the petrol level to be higher than was intended. This must be corrected as described later.

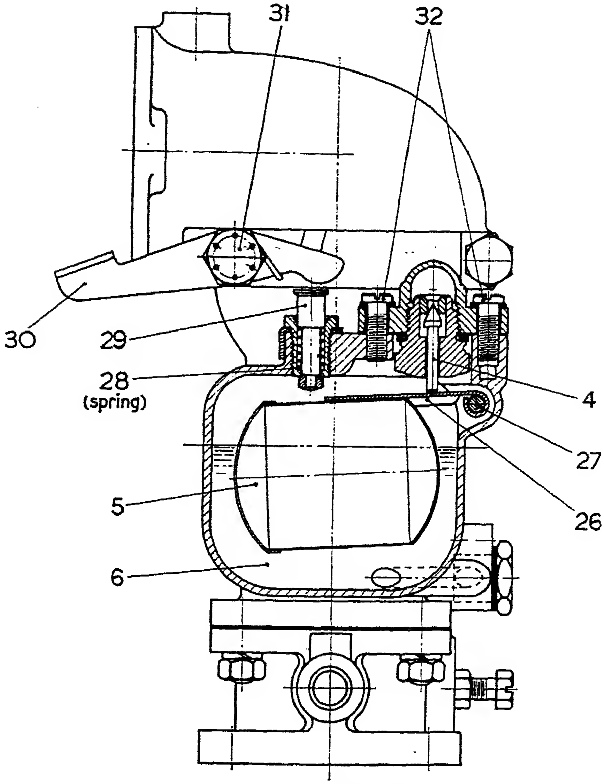


Fig. 2.—SECTIONAL DIAGRAM OF FLOAT

(*b*) **The Needle and Seating**

Unless the needle makes a perfect joint with its seating, petrol will continue to enter the float chamber, even when the desired level has been attained. Again the result will be at least a high level.

The complete needle and seating assembly can be inspected by removing the two holding screws (Fig. 5). Before doing this, however, the petrol plug must be disconnected from the petrol-pipe banjo 3. Careful turning of the hexagon head of the plug 2 anticlockwise will enable this part to be withdrawn. The needle and seating assembly can now be lifted

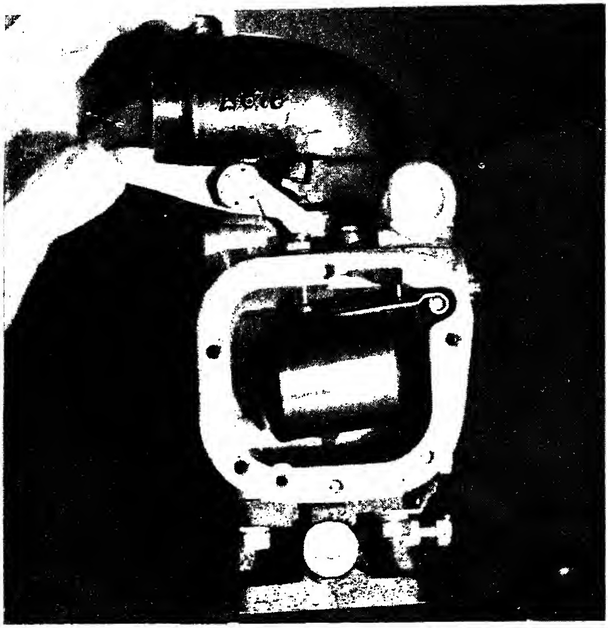


Fig. 3 (Left).—Flooding carburettor by means of "tickler"

clear once the retaining screws 32 have been removed. Dirt may have prevented the needle seating working perfectly. This is likely to be readily apparent, and should be removed by air pressure and washing in petrol. Should there be the slightest indication of wear having occurred — and wear will eventually take place—then the complete assembly must be replaced.

There is a washer placed between the needle seating 1 and its housing. It is most important that this is petrol tight. If the washer is at all faulty, it must be replaced. Indeed,

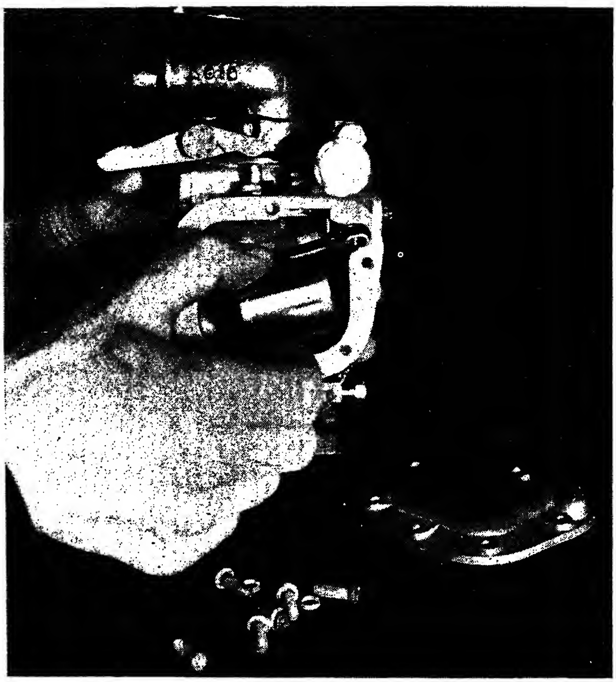


Fig. 4 (Right).—Removing the float

This can be slid off the pivot pin after removing the side of the float chamber by taking out the five retaining screws.

if ever the seating is removed from its housing, a new washer must be used when reassembling. It is imperative that the seating should be tight in its housing. Should it not be so, petrol will seep into the float chamber, despite the fact that the float may be forcing the needle on to its seating to prevent fuel entry through the legitimate channels.

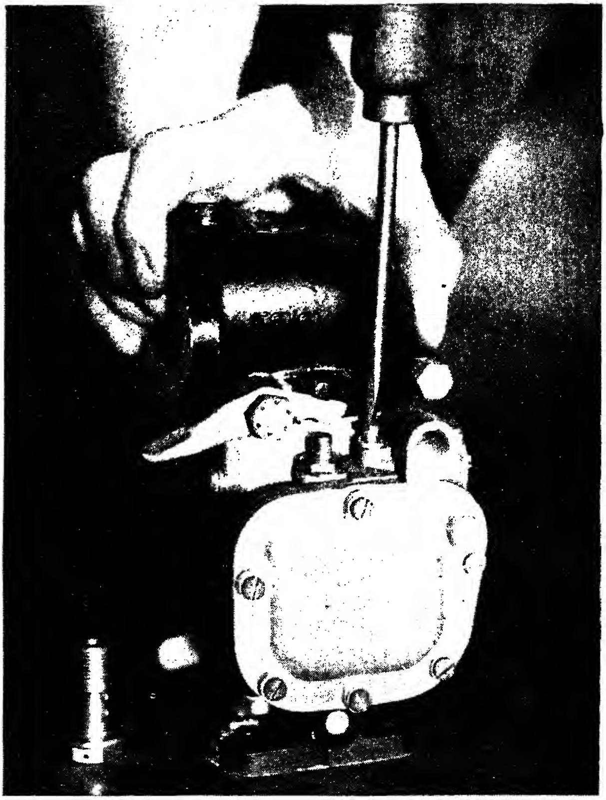


Fig. 5.—REMOVING NEEDLE SEATING ASSEMBLY

(*c*) **Fuel Pressure**

Petrol is fed to the carburettor by means of a fuel pump. The size of the needle and seating is such that it can withstand this pressure, and a reasonable excess pressure when the camber is full and the float is closing off supply. Should the needle or seating be faulty or of a size greater than intended, the pressure will overcome the resistance of the float and cause unwanted petrol to enter the chamber. The same flooding would result if pump pressure exceeding allowable limits was built up. Although a smaller seating could cure this pressure fault, such procedure should never be adopted. It would only result in fuel starvation under full throttle conditions. The only correction to be considered is that of adjusting the fuel pump to give its intended pressure.

Petrol Level

The correct level for the fuel under 6 ft. static head is 76 mm. from flange face. Should the level be higher or lower than this when the foregoing possibilities affecting level have been checked and found correct, moderate adjustments can be made by placing additional washer(s) be-

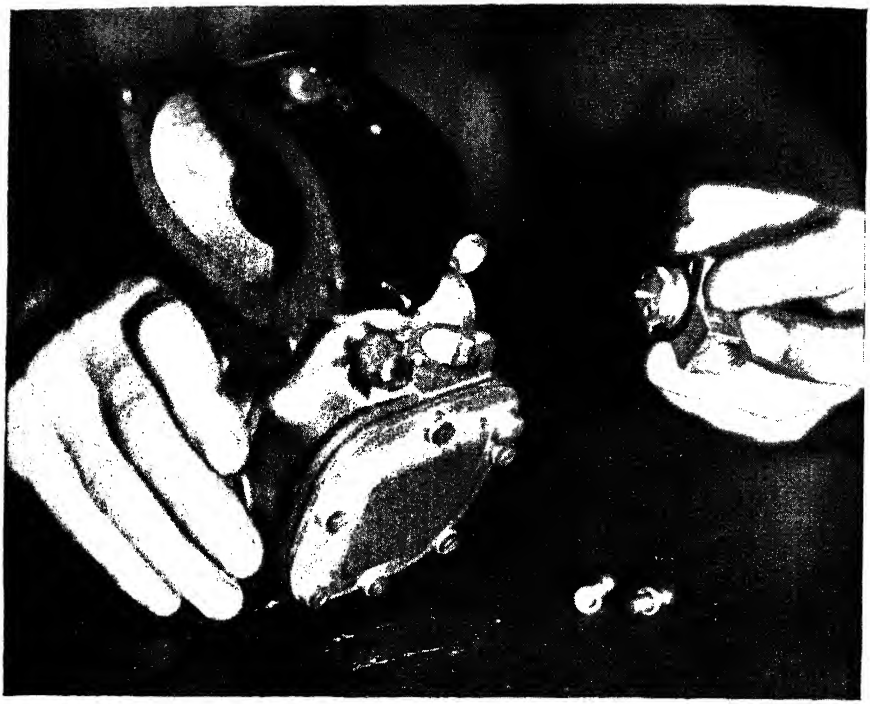


Fig. 6.—NEEDLE SEATING ASSEMBLY REMOVED

tween the needle seating and its housing to lower the level, or by bending the float upwards in relation to its arm to raise the level. Care must be exercised if the latter operation is undertaken. It is safest to hold the arm between narrow, flat-nosed pliers as near the float as possible and then gently bend the float upwards.

General

Handle the float delicately. Resist the common temptation to test the strength of float by pressing it between thumb and forefinger. No purpose will be served by so doing, and as the very nature of its task demands that it is of light construction, the strength test is most surely to result in the collapse of the float walls.

Ensure that the float arm 26 works with perfect freedom on its pivot 27. Lubrication is of course completely out of the question, but it must be clean at all times to prevent binding; otherwise fuel-level control cannot be accurate.

The Idling System

An entirely separate system is incorporated in the carburettor for idling or slow-running purposes (Fig. 7). Petrol supply for this system is

ZENITH TYPE 40 FAIH CARBURETTOR

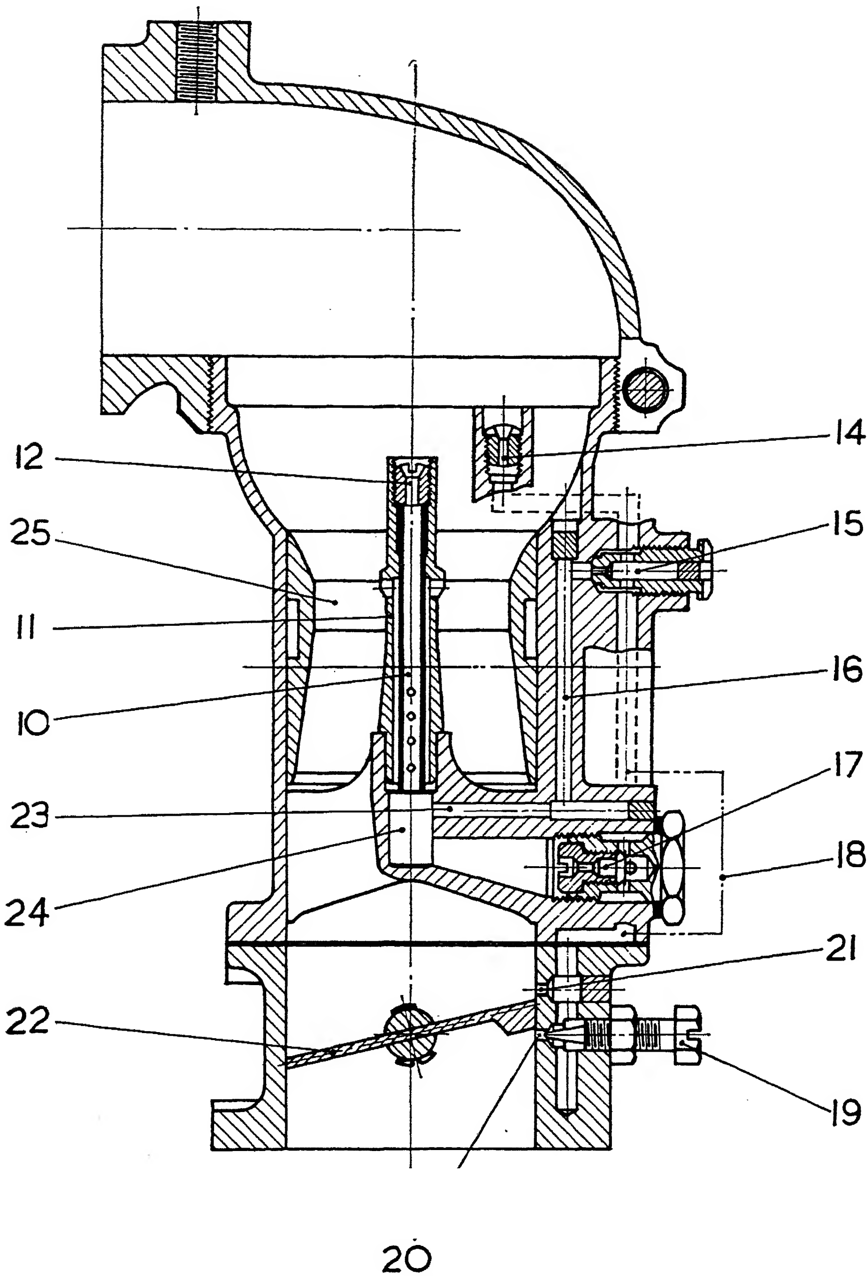


Fig. 7.—SECTIONAL DIAGRAM OF IDLING OR SLOW-RUNNING SYSTEM

from the base of the main-jet assembly. From here it proceeds along a horizontal drilling 23 to the vertical passage 16. Under non-working conditions, petrol will rise in this passage up to the normal fuel level.

When the crankshaft of the engine is rotated with the throttle closed, as shown in Fig. 7, a strong depression or suction is created at the drilling 20 in the barrel of the carburettor. This depression will be present throughout the length of the passage which terminates at the air jet 14. The amount of depression admitted to the drilling 18 depends to some extent on area of the opening 20 which it can be seen is controlled within certain limits by the tapered screw 19.

Breaking into the passage is the pilot or idling jet 15 ; it will be seen that this jet communicates with the drilling 16 which, as already described, contains petrol up to a predetermined level. The presence of depression or suction in the passage 18 will consequently have the effect of extracting petrol from the drilling 16 and air from the jet 14. The petrol is metered by the idling jet 15, and is partly broken up by the air from jet 14. This mixture will proceed down the passage 18 and break out into the bore of the carburettor at 20.

From this point the fuel will be still further broken up by air passing around the throttle valve 22. It is then carried by manifold depression into the engine and provides the fuel mixture necessary for idling purposes. The level of petrol in the drilling will now fall, but replenishment will continue from the base 24 of the main-jet assembly which is in communication with the float chamber.

It will now be seen that four factors are concerned with the eventual output of fuel mixture for idling purposes :

(1) Size of idling jet 15.
(2) Size of air jet 14.
(3) Adjustment of volume-control screw 19.
(4) Adjustment of throttle screw 8 (Fig. 1).

(1) Idling Jet

This part determines the quantity of petrol that is supplied for idling purposes. As will be seen later, the output of the jet is finally decided by adjustment of other parts. It is not anticipated that any different jet size to that fitted in the carburettor will ever be required, but if it is ever found impossible to obtain satisfactory slow running with the existing jet, after making all possible alterations within the range of the adjustment of the parts to be detailed next, then alternative sizes should be tested. A larger jet will be required to provide a richer mixture and smaller for a weaker mixture.

To remove the jet, it is only necessary to turn the head anticlockwise and the jet will screw out. Always keep the idling jet clear of obstruction, and ensure that it is screwed right "home."

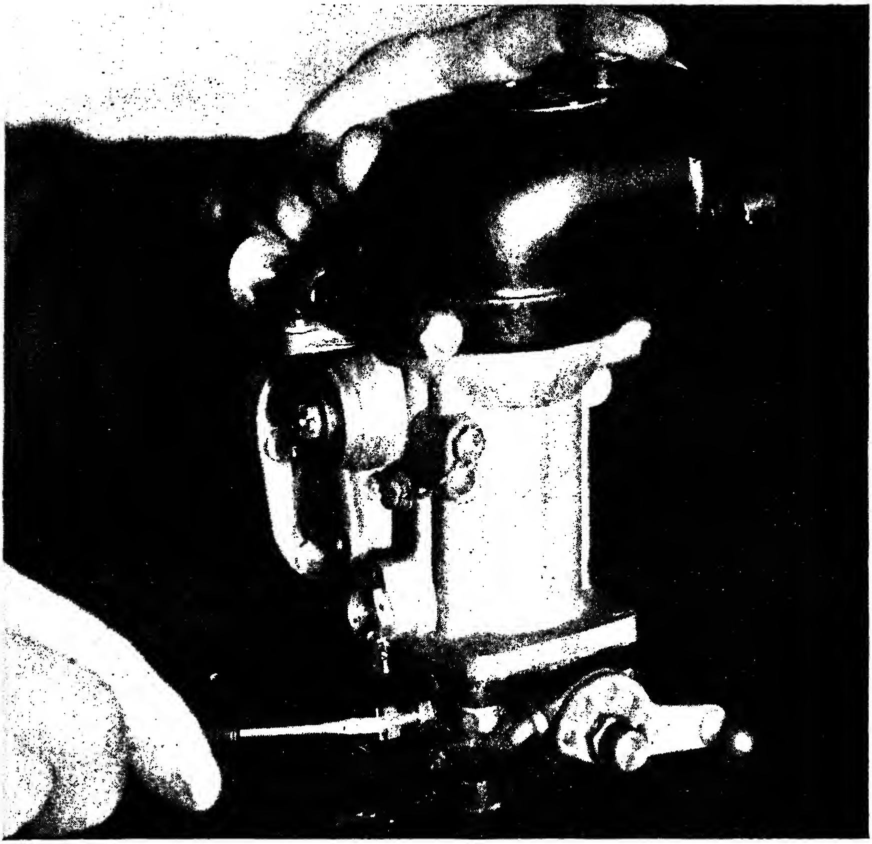


Fig. 8.—ADJUSTING IDLING MIXTURE STRENGTH
This is done by turning the volume control screw.

(2) Volume-control Screw

The purpose of this screw 19 is to control the extent of depression or suction on the idling system. As the cross-section drawing (Fig. 7) shows, it is a tapered screw that projects into the idling drilling 20 below the throttle plate. The farther the taper of the screw projects into the drilling, the less will be the depression that can be transferred from the area on the engine side of the throttle to the main idling drilling. It has been seen that this depression is exerted upon the idling jet 15 to draw petrol from the drilling 16. Consequently, if the depression is reduced, less petrol will be supplied for idling or vice versa. It will now follow that if it is desired to weaken the slow-running mixture, the volume screw 19 must be turned in a clockwise direction. The opposite rotation will be necessary to enrich the mixture.

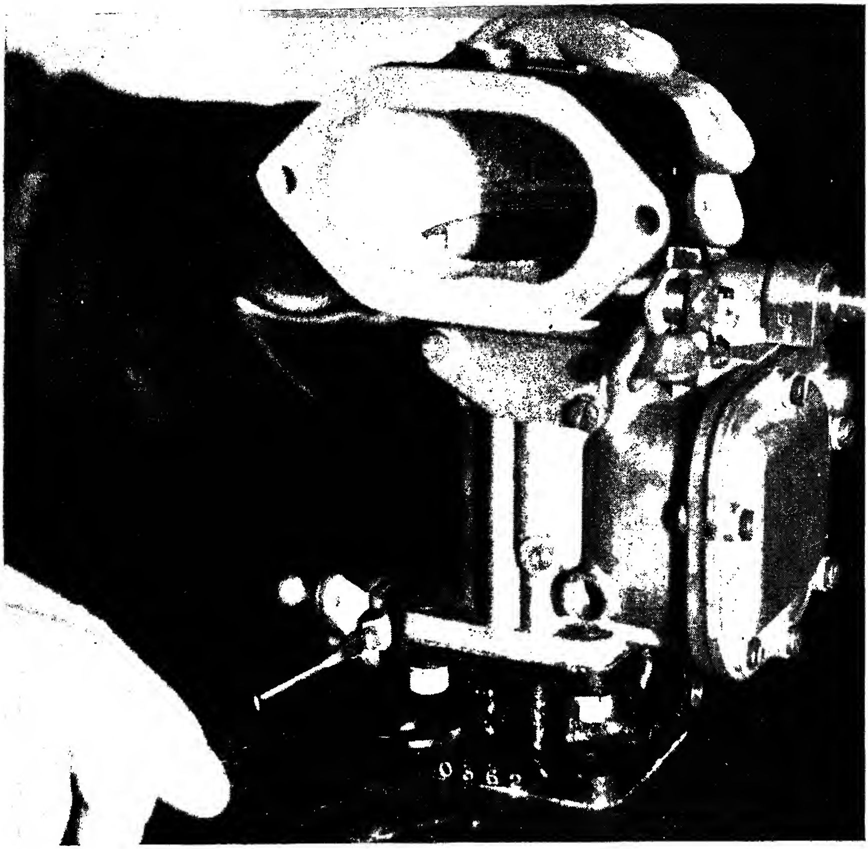


Fig. 9.—Altering speed of idling
This is done by turning throttle stop screw.

To alter the setting of the screw, release the lockscrew and turn the volume control as desired by means of a screwdriver. When the best setting has been found, relock the screw, at the same time ensuring that the volume screw is not inadvertently altered.

(3) Throttle Stop Screw

When it is desired to change the speed at which the engine idles, the slow-running position of the throttle plate must be altered. The position is determined by stop screw 8 (Fig. 1). This screw abuts on to the plate 9. If the screw is turned in towards this abutment plate, the throttle will be opened wider and the engine speed will increase. To reduce the speed of idling, the stop screw will, naturally, be turned anticlockwise away from the plate. Here again a locknut must be released before it is

possible to make any adjustment, and carefully relocked when the desired idling speed has been attained.

(4) Idling Air Jet

A permanent air bleed to the idling system is provided by the jet 14. This, it will be seen (Fig. 7), is placed just inside the air intake of the carburettor and is consequently open to atmospheric pressure. When there is depression in the idling system, air will be drawn in through the jet 14. The effect will be to atomise partly the petrol that is passing from the idling jet, and also to provide a certain release of the depression that is being exerted upon the idling jet.

It follows therefore that the larger the size of the air jet, the weaker will be the fuel supplied for slow running. The size is carefully deter mined at the factory and no alteration is needed.

Opening Up Throttle

To prevent the tendency of a " pause " in the fuel supply when opening up the throttle plate to increase engine revs., another drilling 21 higher in the barrel of the carburettor is provided in the idling system. Depression at the lower drilling 20 will drop when the throttle is opened a little wider, but it will increase at the higher drilling 21, and consequently fuel will continue to be supplied from the idling system. If this arrangement was not provided, there would be a " pause " or a " flat-spot " in the changing over from the idling to the main carburettor system.

No adjustment is possible to this progression drilling, as it is a fixed size.

Main Carburettor

Opening the throttle beyond the idling system has the effect of increasing the depression higher in the barrel of the carburettor. This depression (or suction) will be greatest at the " waist " of the choke tube 25. Situated in the centre of this area is the outlet of the main discharge assembly 10. Whilst retaining this point clearly in mind, let the construction of the assembly, and the petrol flow to it, be detailed.

A drilling 7 from the float chamber feeds petrol to the main jet 17. This jet measures the petrol that is allowed to pass to the main assembly. Inside this assembly runs a tube 10, an air jet 12 is situated at the top of the tube, and holes are drilled through the base. These holes give the inside of the tube access to the annular space between the tube and its outer housing 11. The head of this annular area is the outlet of the main discharge assembly which has already been detailed as being situated at the " waist " of the choke tube. Depression (or suction) is greatest at this area, and the effect is to draw out the petrol standing in the lower part of the assembly.

Once the level of petrol falls below the top hole drilled in the tube 10, depression will also be present inside the tube. This will cause air to be drawn into the system through the jet 12. As the petrol level continues to fall, the other holes, and eventually the base of the tube, are uncovered, and greater depression is made on the air jet 12. This is the fuel-compensating system essential to ensure the maintenance of the desired petrol-air ratio at all engine speeds under varying throttle positions.

As the petrol leaves the outlet holes of the main discharge assembly, the inrushing air through the choke tube takes up the fuel, atomises it, and carries it past the throttle plate in the induction manifolding and so into the engine.

With the throttle opening wider and wider under the same engine load, depression on the discharge assembly increases and a greater output results. In this manner, the increased volume of fuel required for higher engine speed is obtained.

ADJUSTMENTS

It will now be appreciated that the factors deciding the fuel output of the main carburettor are:

(1) The area of the choke tube 25.
(2) The size of the main jet 17.
(3) The size of the air jet 12.
(4) The degree of throttle opening.

(1) Choke Tube

Under all normal circumstances, there will never be any necessity to vary the size of the choke tube 25. After most exacting tests by the manufacturers, a size was decided upon that would give all the desired results.

To understand in full the complete adjustments carburettor engineers can adopt when conditions indicate, however, variations and effects of this part will be detailed.

The size of the choke tube is known by its smallest internal measurement in millimetres. Consequently, the narrowest inside measurement of the standard choke tube on the De Havilland 40 FAIH carburettor is 31 mm. and the figures will be found stamped on the top inside face of the choke tube.

The object of the choke tube is to control the maximum volume of fuel that can pass from the carburettor to the engine, and to assist in maintaining desired air speed through the carburettor. Its internal shape is such as to ensure the concentration of depression upon the desired portion of the main-jet assembly.

The effect of fitting a larger choke tube is to enable a greater volume of mixture to pass through the carburettor. If the engine is capable of taking advantage of this greater supply, more power and higher speed

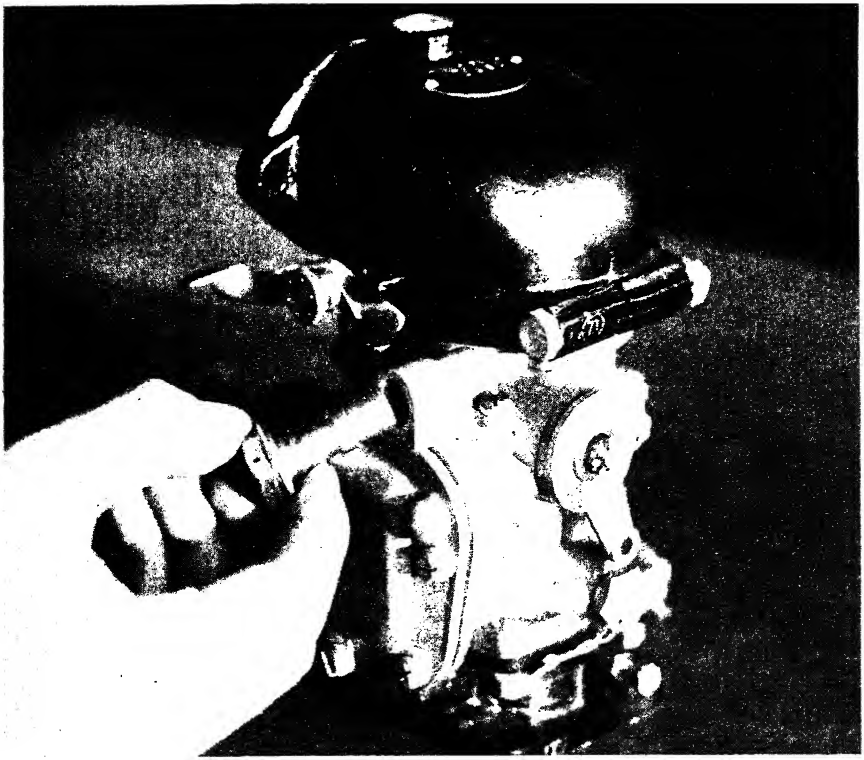


Fig. 10.—Removing petrol filter plug

are attainable. At the same time, the fitting of a choke with larger internal area will cause the speed of the mixture passing through the carburettor to decrease, with a consequent " falling off " in acceleration performance.

The installation of a smaller choke tube has the reverse effects. Volume is reduced and velocity is increased. That means power and speed are less, but acceleration is improved.

It follows, then, that the ideal area of choke tube is the smallest that will give the desired power from the engine.

Changes of choke-tube sizes will naturally affect the petrol output from the main-jet assembly. The smaller choke results in an increase of depression at the jet outlet for a given throttle opening and more petrol will be extracted. Conversely, the depression is less with a larger choke and petrol output will also be reduced. It is these facts that make it necessary to change jet sizes accordingly when variations are made to choke-tube sizes.

(2) Main Jet

It has been seen that this jet 17 controls the flow of petrol from the float chamber to the main assembly. Its effect is felt, particularly during the early part of the throttle range. Consequently, if starvation or richness is apparent during this period, a suitable change of main-jet size should be tried. A larger jet is necessary if weakness is suspected. Richness may be corrected by employing a smaller jet. Here again, however, it is most unlikely that any change in jet size will be required under anything like normal conditions. The carburettor engineers have only decided upon the size of jet standardised, after lengthy tests of all alternatives. It is important, however, that the jet is clean at all times. To remove the jet for inspection, apply a spanner to the head of the jet and turn anticlockwise. The jet will then screw out.

(3) Air Jet

The object of jet 12, as already described, is to act as a correction on the main jet 17 to ensure mixture compensation. For this reason it is often known as a correction jet.

As engine speed increases, the downward air current from the jet progressively interferes and restricts the upward movement of the petrol from the main jet. Consequently, the higher the engine speed, the greater will be the effect of the air jet 12. As a result, if difficulty is ever experienced during the latter part of the throttle range, it is often possible to adjust by altering the size of the air jet.

A larger correction (or air) jet will obviously weaken the mixture and vice versa. To remove the jet, it is first necessary to take off the air intake cover. A screwdriver can then be applied to the jet accordingly.

Altitude Correction

It is known that as the aeroplane ascends in altitude the atmosphere decreases in pressure, temperature, and density. The weight of the charge taken into the engine decreases with the decrease in air density, cutting down the power in about the same percentage. In addition, the mixture proportion delivered by the carburettor is affected, the mixture becoming richer.

In order to compensate for this change in mixture an altitude-corrector valve is embodied in the carburettor. Normally the fuel in the float chamber is subject to atmospheric pressure, the release being assured by the air-vent jet 13. Now, the output of the jets is dependent upon the difference between the pressure in the float chamber and that ruling in the choke tube. Briefly, the object of the altitude corrector is to lower the pressure in the float chamber so that the mixture output from the jet assembly is weakened. To bring the corrector into operation the lever 34 is pulled towards the float chamber. This brings the drilling 33 into communication with the drilling 35. It will be seen that the passage 33

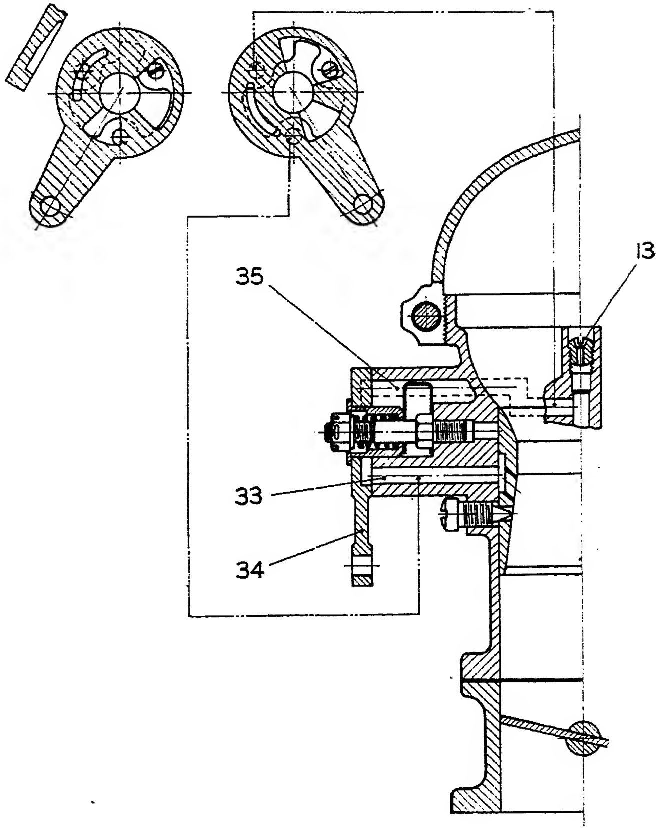


Fig. 11.—ALTITUDE-CORRECTOR VALVE

breaks into the choke area below the "waist" of the tube. Consequently the depression at this point will now be felt in the drilling below the air-vent jet 13 to the float chamber. In this manner depression in the choke area which is lower than normal atmospheric pressure is transferred to the float chamber. The degree of depression transfer depends upon the amount of valve opening. Consequently the mixture output can be weakened to a varying degree by means of the altitude corrector and thus overcome the natural tendency that exists for mixture to become rich as altitude is attained.

Locking of Parts

To prevent any possibility of certain parts of the carburettor coming adrift through vibration, they are wired. It is, of course, of utmost importance that the parts should be rewired if at any time the seals have been broken for the purpose of removing the parts. The parts so wired are as follows :

(1) Main jet 21 (to collar provided on one of the four bolts holding the throttle-valve body to the carburettor barrel).

(2) Idle jet (to screw retaining choke tube).

(3) Correction jet 12 to (4) Air-vent jet 13.

(5) Idle-air jet 15 (to own housing).

(6) Throttle spindle nut (to one of the five holes in the throttle control lever).

(7) The petrol union plug 2.

Additionally the screws holding the throttle plate to its shaft are soldered over.

Jet Setting

Choke tube	31 mm.
Main jet	520 c.c.
Main-jet bleed	1·75 mm.
Altitude corrector . . .	2·30 mm.
Idling jet	0·85 mm.
Petrol lever under 6-ft. static head .	76 mm. from flange face.
Needle seating	2·5 mm.

THE ROLLS-ROYCE KESTREL CARBURETTOR

THIS carburettor is entirely designed and built by Rolls-Royce Limited. It is of the twin-barrel type, i.e. with two throttle bores, two choke tubes, etc., fed by a common air intake. A pilot jet and a small auxiliary diffuser are incorporated and are solely for starting and small throttle openings. The point where the mixture enters the air stream can be adjusted so that it varies relative to the edge of the throttle valve and this adjustment enables the blending of the slow-running and main mixtures to be adjusted so that no irregularity or flat spots occur as the throttle is opened up. This small diffuser system is fitted with a filter.

Control of Main Fuel Supply

Control of the main fuel supply by the pilot is obtained by rotary fuel valves which he can alter according to varying altitudes, etc. Acceleration with quick throttle opening is assured by an accelerating pump built into the carburettor which injects a temporary discharge of fuel into the left-hand choke through a nozzle provided for that purpose.

Fig. 1 shows a section through the carburettor, the upper half of which is fixed to the supercharger casing, while the air supply is drawn through a gauze-covered frame held in place by the air-intake flange, which usually faces forward. Referring to Fig. 1, it will be seen that fuel is delivered to the float chamber at the union A, the level being controlled by a float and needle valve B. From the float chamber fuel passes via two valves E, the valves having eccentric heads each working in its own seating. A passage from each of these seatings goes to the diffuser wells, the passages being restricted by the eccentric valves which are joined together by short levers and a connecting link and can be opened or closed by moving the pilot's lever D.

The Air Bleed

Projecting down into the diffuser wells will be seen two tubular parts, in the sides of which are a number of small holes, and the diffuser wells connect with the diffuser nozzles projecting into the chokes. The upper parts of the diffuser tubes are connected by the passages F, the annular space around the chokes, and from there to the carburettor air intake. When the engine is running the air pressure in the passage F is higher

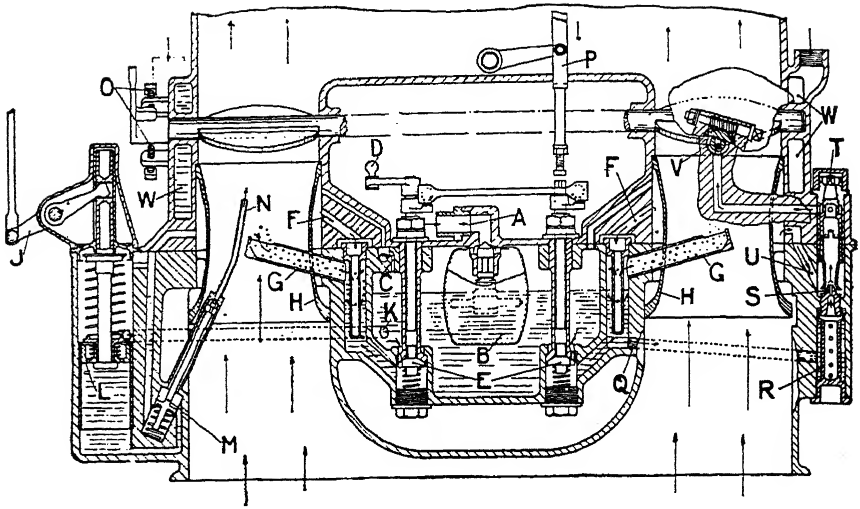


Fig. 1.—SECTION THROUGH THE ROLLS-ROYCE KESTREL CARBURETTOR

A. Fuel inlet.
B. Float.
C. F.C. air vent and ball valve for inverted flying.
D. Mixture control (main jet).
E. Eccentric varying the M.J. flow.
F. Air bleed to main diffuser.
G. Main diffuser nozzle.
H. Choke.
J. Accelerating pump lever connected to throttle control lever.
K. Fuel supply to accelerating pump.
L. Accelerating pump.
M. Spring-loaded needle valve.
N. Accelerating pump discharge nozzle.
O. Main throttle-operating lever and stops.
P. Mixture-strengthening device (connected to throttle-operating lever).
Q. Fuel supply to S.R. jet.
R. S.R. filter.
S. S.R. jet.
T. S.R. mixture adjustment.
U. S.R. air supply.
V. S.R. adjustment plug.
W. Hot-water jacket.

than in the nozzles G, with the result that air passes through small holes in the diffuser tubes and bubbles through the fuel in the diffuser well. The resulting rich emulsion passes through the tubes G into the choke tubes where it mixes with the main air supply and passes up into the supercharger intake and so to the engine. Fig. 2 shows a section through the engine and carburettor.

Slow Running

In common with many other carburettors, when the throttles are in the nearly closed or slow-running position, the pressure difference between G and F is insufficient to supply fuel from the main jet system. A feed is therefore taken to a plug V opposite the lower edge of the right-hand throttle valve. This plug has the discharge orifice in it placed eccentrically, so that turning the plug will raise or lower the hole relative to the edge of the throttle valve, the hole, however, being of such a size that

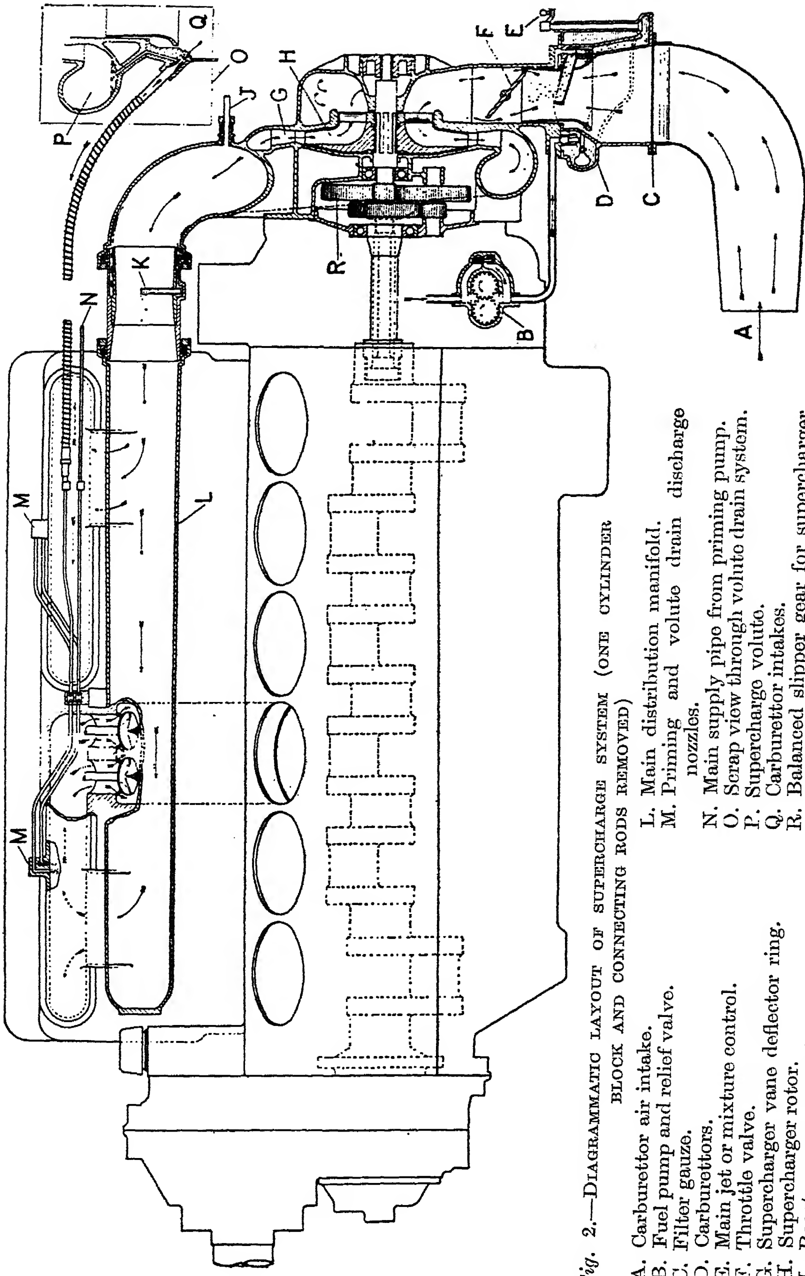


Fig. 2.—Diagrammatic layout of supercharge system (one cylinder block and connecting rods removed)

A. Carburettor air intake.
B. Fuel pump and relief valve.
C. Filter gauze.
D. Carburettors.
E. Main jet or mixture control.
F. Throttle valve.
G. Supercharger vane deflector ring.
H. Supercharger rotor.
J. Boost gauge connection.
K. Redistribution pipe for condensed fuel.
L. Main distribution manifold.
M. Priming and volute drain discharge nozzles.
N. Main supply pipe from priming pump.
O. Scrap view through volute drain system.
P. Supercharge volute.
Q. Carburettor intakes.
R. Balanced slipper gear for supercharger drive.

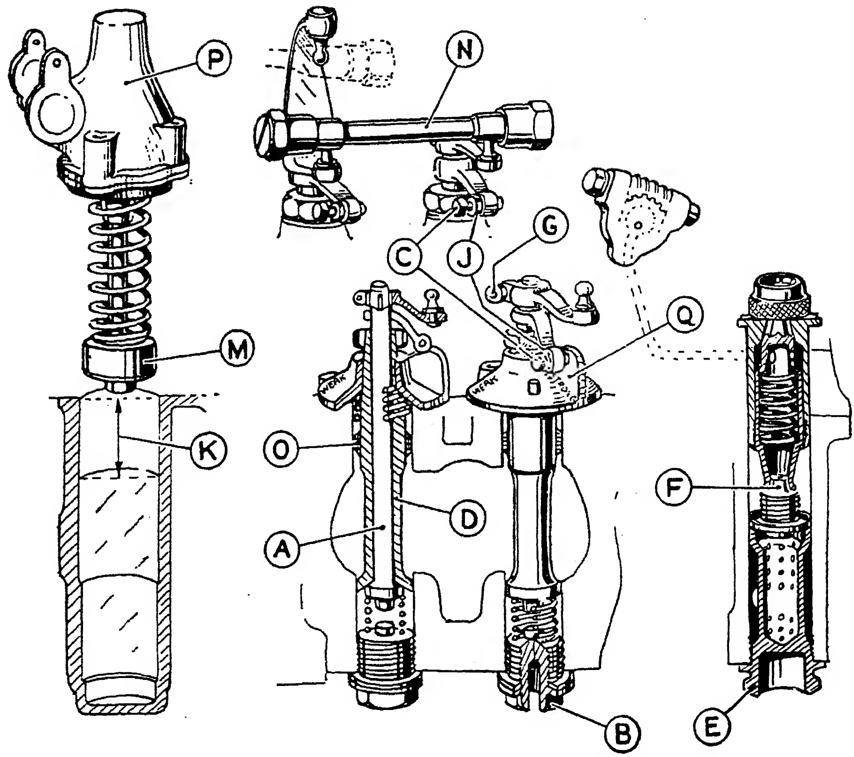


Fig. 3.—Accelerator pump, fuel level, mixture controls, and slow-running adjustments

part of it shows both above and below the throttle, the proportion varying with the amount of rotation given to the plug.

In this way the mixture strength issuing opposite the edge of the throttle can be varied. If a small gap is on the underside and a large one on the engine side, the mixture will be rich. If small on top and large underneath more air will enter and the mixture will be weak, any range of mixture strength between the two extremes being obtainable by turning the plug to the required position. The fuel for slow running comes from the right-hand main jet and flows to the small auxiliary diffuser, through gauze filter R and then via passage Q and jet S to the discharge plug U.

Acceleration

If a carburettor is tuned to be economical, sudden opening of the throttle from the slow-running position will cause a bad hesitation or "flat spot," as it is commonly called, and a temporary injection of fuel

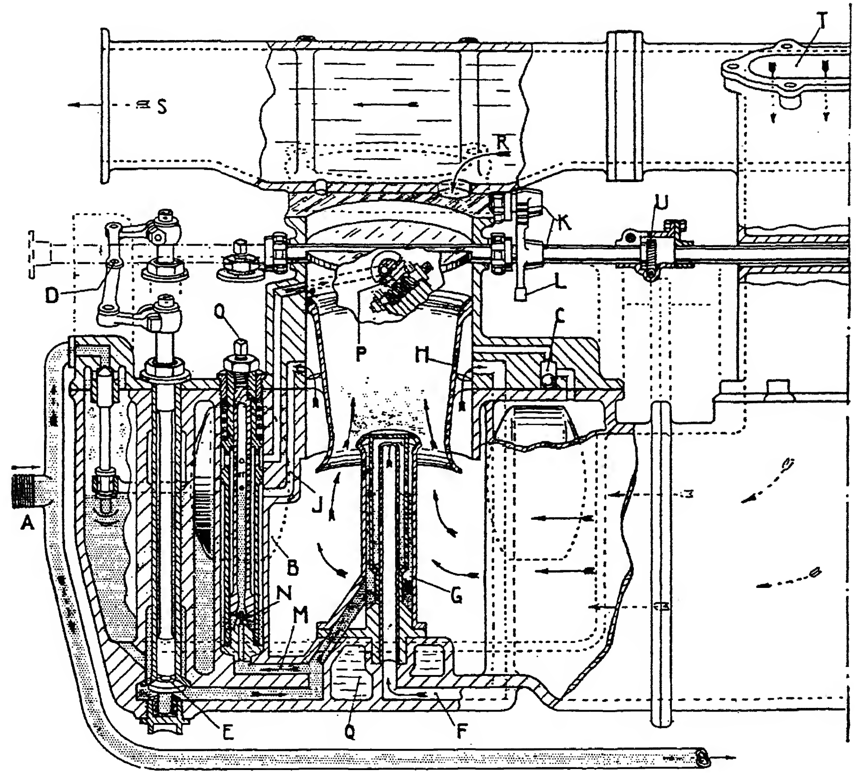


Fig. 4.—DIAGRAMMATIC SECTION OF CARBURETTORS FOR NORMALLY ASPIRATED ENGINES

A. Fuel inlet.
B. Float.
C. Float chamber air vent and ball valve for inverted flying.
D. Mixture (main jet) control.
E. Eccentric varying main jet flow.
F. Air bleed to main diffuser.
G. Main diffuser nozzle.
H. Choke.
J. Air supply to slow-running device.
K. Main throttle shafts coupled by quadrant.
L. Throttle stop lever.
M. Fuel supply to slow-running jet.
N. Slow-running jet.
O. Slow-running mixture adjustment.
P. Slow-running adjustment plug.
Q. Hot-water jacket.
R. Supply to water jacket.
S. Main water outlet pipe.
T. Air intake.
U. Worm adjustment for synchronising front and rear throttles.

must accompany this sudden opening. Reference to Fig. 1 shows an accelerating pump L which is coupled to the pilot's throttle lever. When this lever is moved rapidly, the spring-loaded valve M is blown off its seat and fuel is discharged into the air stream through the pump discharge nozzle N. Slow opening of the throttle does not require accelerating pump action, and in such an instance the pressure is insufficient to open

valve M and the fuel displaced by the pump piston is by-passed through a valve in the piston itself.

"Take-off" Mixture Strength

When the pilot's throttle is put through the "gate" to the "take-off" position, it is necessary to enrich the mixture strength to counteract the detonation that would accompany the raised boost pressure. Connected to the pilot's throttle lever is the plunger P, which under "take-off" conditions is pressed downwards. This pushes one of the fuel valves E off its seat and in this way allows the necessary extra fuel to enter the air stream via the diffuser nozzle G. The movement of the plunger P is adjustable and ranges from one extreme, where it is inoperative, to a maximum depression of right-hand valve E of 30 to 40 thousandths of an inch.

Heating

A hot-water jacket is formed round the diffuser chambers to minimise the risk of freezing, the water being drawn from the top of the carburettor and taken to the suction side of the water pump. To avoid deposition of fuel in the supercharger casing, a venturi drain is fitted and can be seen in Fig. 5, marked V.

Dismantling for Cleaning

The following parts should be removed (*see* Figs. 3 and 5) :—

1. Main air bleed tubes and nozzles with chokes (downwards).
2. Unscrew plug B at the base, remove top controls and main metering valves A (*see* Fig. 3).
3. Unscrew slow-running filter E and the jet F.
4. Remove accelerating pump M and needle valve.
5. Remove float C and the pivots H (*see* Fig. 5).
6. Remove glands O (Fig. 4) and seating D (*see* Fig. 3). Thoroughly blow out and clean all passages.

Check float spindle for end play and wear, also see that the metering valve seats are free from abrasion and are quite fuel-tight. Examine the float cut-off contacts and carefully polish the face of the needle valve (*see* Fig. 5).

See that every part is scrupulously clean, reassemble the parts in the same order and make the following tests. Failing the usual type of level test apparatus, bolt the carburettor to the engine and connect up the main gravity fuel feed. Check that the float mechanism shuts off properly and that the fuel level does not creep.

The Flow Test

The next process is to reset the metering valves so that they give the correct flow and is as follows. See that the pinch bolts G are slack and

CARBURETTOR SETTINGS

Kestrel Engines—Series :	*B to B3.*	*MS2.*	*S3 to S5.*	*IV to VI.*	*VII to IX.*	*X to XII.*	*XIV to XVI.*
Main jet, full strong, under 2 ft. head, pts./hr.	43·5	65·0	65·0	68·0	68·0	43·5	100·0
Percentage range to full weak	52·0	42·0	42·0	67·0	67·0	52·0	60·0
No. of main jets per engine	4·0	2·0	2·0	2·0	2·0	4·0	2·0
No. of pilot jets per engine	4·0	2·0	2·0	1·0	1·0	4·0	1·0
Pilot-jet calibration, c.c./min.	155·0	120·0	120·0	400·0	350·0	155·0	400·0
Fuel level under 12 ft. head	0·875	0·825	0·825	0·475	0·475	0·875	0·475
Fuel level under 2 ft. head	1·075	1·225	1·225	—	0·700	1·075	0·700
Enrichment depression full rate	—	—	0·040	0·040	0·040	—	0·040
Enrichment depression de rate	—	—	—	0·015	0·015	—	0·015
Working heads, ft.—max	12·0	12·0	12·0	12·0	12·0	12·0	12·0
Working heads, ft.—min.	2·0	2·0	2·0	—	2·0	2·0	2·0

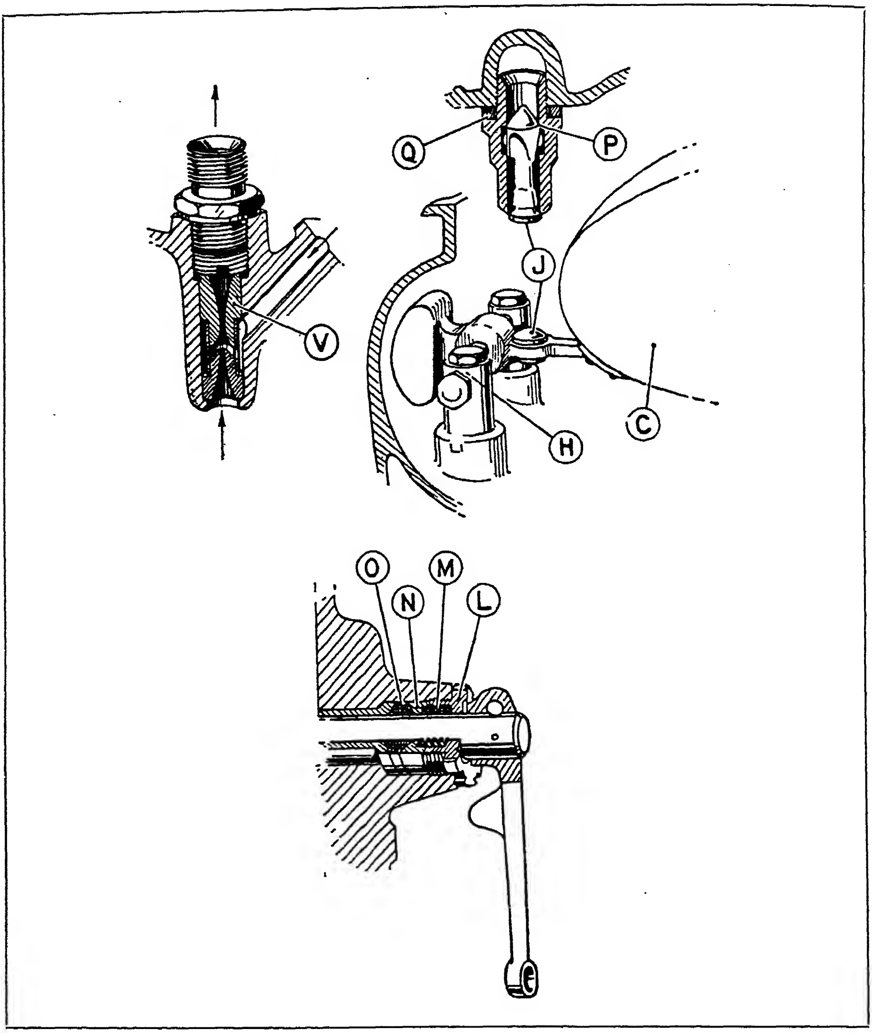


Fig. 5.—Sections through volute drain venturi, float needle valve, counterweights, and throttle gland

that the accelerating pump cover is not in position. The flow test should then be made.

1. Replace the plug and spring below the left-hand valve.

2. Insert a special drilled plug and a spring below the *right-hand* valve. The spring is necessary to keep the valve on its seat.

3. Turn on the fuel supply and when a steady flow is obtained, vary the rotational adjustment of the valve until 1 pint of fuel flows in 36

seconds, a suitable measuring vessel being used. This setting is the "full rich" position, and most be limited by the stop screws C, which must be locked by the nuts J.

4. Turn the valve to the "weak" position and recheck the flow. This should be 1 pint in 90 seconds.

The Rolls-Royce carburettor is a precision-made instrument and must be handled and adjusted with the care that all precision instruments warrant, and above all scrupulous cleanliness must be observed.

STROMBERG NA-S2 AND NA-S3 CARBURETTORS

THE Stromberg NA-S2 and NA-S3 carburettors are designed to meet the exacting requirements of small two-, three-, and four-cylinder aircraft engines, such as are used in small aeroplanes. The principles of operation as described in these instructions are quite similar to those used in all Stromberg carburettors. The specification or setting in the carburettor is the result of a great deal of test work conducted by the engine and carburettor manufacturers in the laboratory and in flight, and should not be changed unless it is absolutely certain that a change is necessary to meet unusual operating conditions. The following notes relate particularly to the Stromberg carburettors used on the Continental engines.

DESCRIPTION AND FUNCTIONING OF CARBURETTOR

Float Mechanism

A conventional hinge type of float mechanism located in a float chamber having ample fuel capacity to operate in all ordinary manœuvres is used. This float mechanism is adjusted by the manufacturers to obtain the proper fuel level, and requires no adjustment in service unless it is necessary after a long period of service to install new parts. For information concerning the proper level see the section of these instructions pertaining to " Overhaul."

Main Metering System

The metering system used in the carburettor is of the plain tube type with an air bleed to the main discharge nozzle. The main discharge nozzle is located at the centre of the venturi and is screwed into a boss projecting into the air intake. The main air bleeder is screwed into the air bleed arm which is held in place by the main discharge nozzle.

The actual metering of the fuel is accomplished by the main metering jet which is assembled in the bottom of the float chamber in a channel through which the gas flows to the main discharge nozzle. The size of the main metering jet affects the fuel consumption at all speeds from approximately 1,000 r.p.m. to full throttle speed.

Idling System

Inasmuch as the main metering system will not function at very low air flows (low engine speed), an idling system is provided. This consists

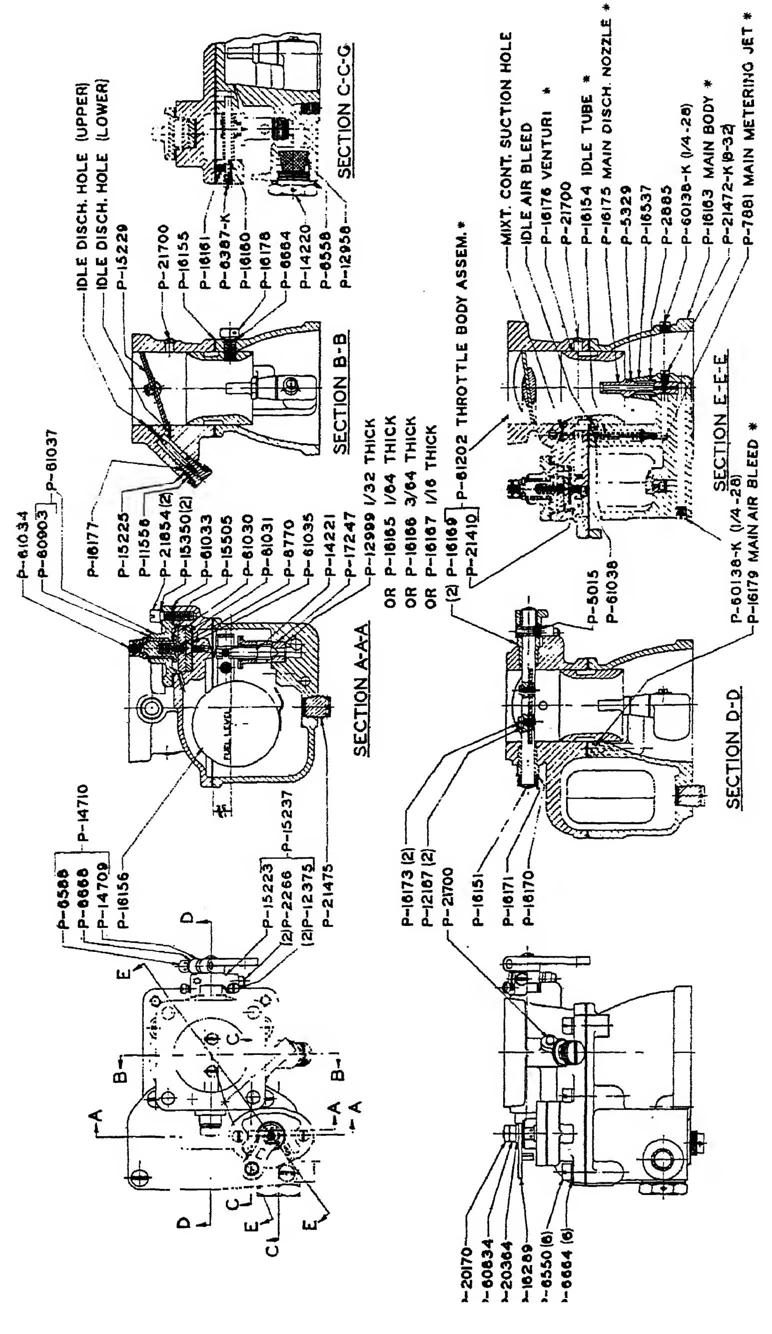


Fig. 1.—Diagrammatic views of Stromberg NA-S2 carburettor

of an idle tube with an idle metering orifice in the bottom and several air bleed holes in the wall, an idle air bleed, and two holes in the throttle barrel, which act as idle discharge nozzles. A needle valve type of adjustment is provided on the upper discharge nozzle, which regulates the quality of the idle mixture.

Fuel for the idle system is taken from the annular space around the main discharge nozzle, passes through the idle metering jet and mixes with the air from the idle air bleed located in the main body behind the venturi. The air enters the tube through the bleed holes and the mixture then passes out of the upper or lower idle discharge hole.

The relative quantities passing through the upper and lower idle hole depend upon the position of the throttle. At extreme idle, all the fuel passes through the upper hole and as the throttle opening is increased, more and more of it passes through the lower hole. The idle system operates up to an engine speed of approximately 900 to 1,000 r.p.m.

Installation

The carburettor should be so mounted on the engine that the float chamber is at the side of the throttle barrel, preferably with the fuel inlet to the rear. With the carburettor in this position, the throttle control lever, which is adjustable to any radial position, is at the right side of the carburettor as viewed from the rear of the engine. The fuel inlet is a $\frac{1}{4}$-in. pipe tap connection located at the back near the bottom of the main body if the carburettor is installed as above. When the fuel level is set by the manufacturers a pressure of one-half pound per square inch at the carburettor is used. As these carburettors will undoubtedly be used on engines having a gravity-feed system, it is recommended that the tanks be located so that the minimum head of fuel on the carburettor inlet is twenty-four (24) inches under all normal conditions of flight.

Starting

As the carburettor is not equipped with a priming device, the following procedure is recommended for starting. With the throttle closed the engine should be turned over two or three times before the ignition is turned on. This will draw fuel up through the idle system and then if the ignition is turned on the engine will usually start on the next turn over. As soon as the engine starts to fire, it is usually necessary to open the throttle slightly to keep the engine running and to warm it up sufficiently for normal operation.

Adjustment

The main metering jet used in the carburettor is of the fixed orifice type, and its size as well as the remainder of the carburettor specifications has been determined by test work as previously mentioned, so that no adjustment for cruising and full throttle speeds is required.

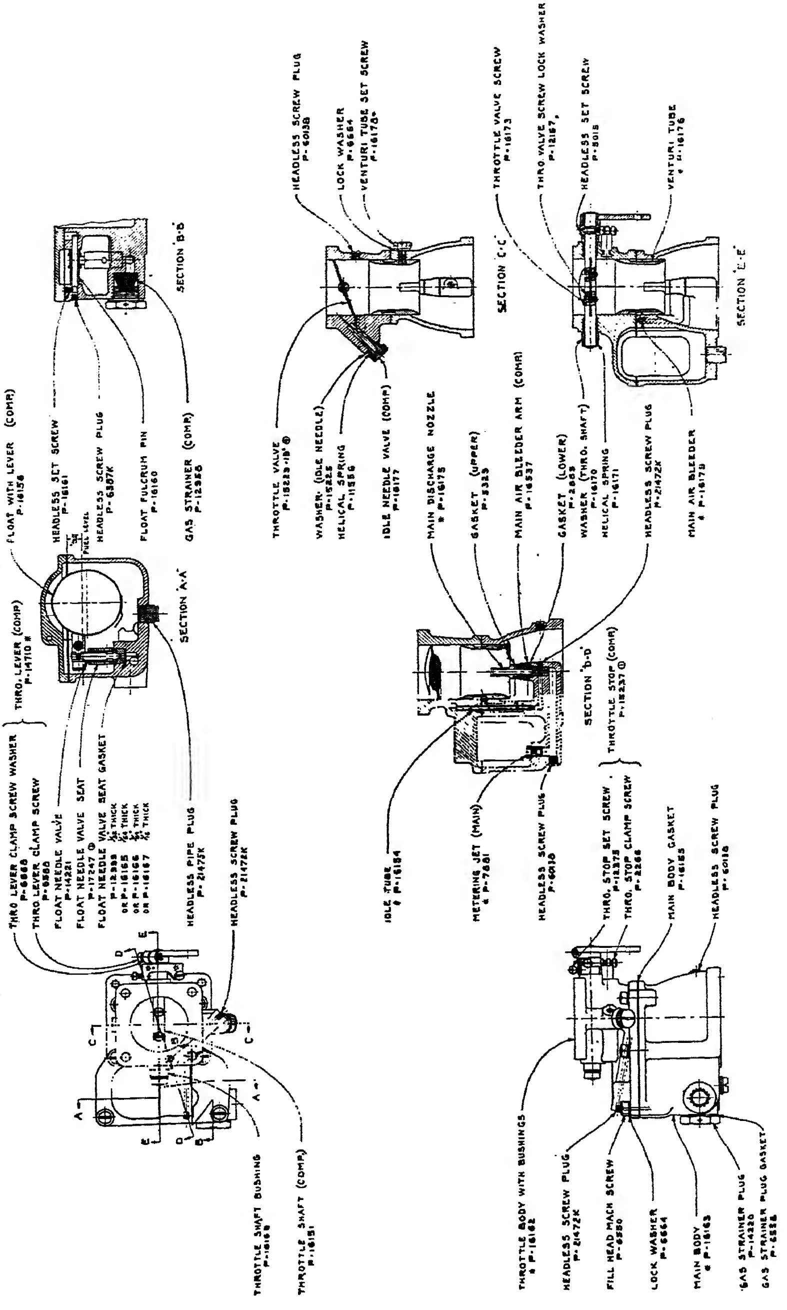


Fig. 2.—DIAGRAMMATIC VIEWS OF STROMBERG NA-S3A1 CARBURETTOR

An idle adjustment is provided to take care of slight production variations in the carburettors and engines. A small knurled screw near the edge of the butterfly valve, on the throttle valve body, may be adjusted to control the richness of the mixture at idling speeds. Turning this screw in a clockwise direction closes off the passage leading to the upper idle discharge hole and leans out the idle mixture. Turning in the opposite direction of course gives a richer mixture.

An Important Point

If the idle adjusting needle is screwed into its seat with too much force, the needle will be grooved and the needle seat in the throttle body will be damaged. This will prevent an accurate idle adjustment and will generally necessitate replacement of the needle and throttle body. Great care should therefore be exercised when adjustment is being made not to turn the needle into its seat more than finger tight. In case the needle has been screwed into its seat by the fingers and the engine is still apparently idling too rich, it is suggested that the engine primer be inspected to see if it is allowing fuel to enter the engine.

Under no circumstances should the idle needle be screwed in with a pair of pliers or by using much force on a screwdriver. A throttle stop is provided on the throttle shaft next to the throttle control lever, which should be adjusted to obtain the desired idling speed. Both the throttle stop and the idle adjustment should be set with the engine hot to obtain the proper idling speed and smooth operation.

Servicing

Once the carburettor is properly installed and the idle adjustment made, very little attention is required in service. A fuel strainer is provided near the fuel inlet of the carburettor, and may be removed by the removal of the large hexagon head plug on the side of the float chamber. A small square head plug is provided as a drain in the bottom of the carburettor. The strainer and drain plug should be removed frequently to get rid of any dirt or water which may have accumulated in the strainer chamber of the float chamber. The entire carburettor should also be inspected to see that all parts are tight and properly safetied.

OVERHAUL

Dismantling

The carburettor should be dismantled for cleaning and inspection each time the engine is given an overhaul. After the carburettor has been removed from the engine and the hot spot and air intake or heater taken off, the halves of the carburettors may be separated by the removal of the filister head screws at the parting surface. The venturi is held in the lower half by a hexagon head screw.

Removal of Float Fulcrum Pin

Remove the set screw which holds the float fulcrum pin in place and the plug at the side of the carburettor, which will permit the removal of the float fulcrum pin. The float and the float needle valve will then come out and it will be possible to remove the main metering jet, which is located below the float. Remove the idle tube which is screwed into the main body. If there is any indication of dirt or foreign matter in the float chamber, it is advisable to remove the main discharge nozzle. The removal of the above parts will permit a thorough inspection and cleaning of the carburettor, and unless replacements are necessary further dismantling is not recommended.

Inspection and Cleaning

The bodies and all parts should be thoroughly cleaned in petrol, and all passages blown out with an air hose.

Float Needle Valve and Seat

The float needle valve and seat should be inspected for wear and if the needle valve is badly grooved, both parts should be replaced. The needle valve is made of stainless steel and the seat of naval brass so that under ordinary service conditions these parts should last for many hundreds of hours.

Main Metering Jet

Check the main metering jet and float needle seat to make sure that they are tight. It is important that the throttle valve fits the barrel tightly when in the closed position and that the lower edge be flush with the top of the lower idle hole.

Reassembly

All headless screw plugs below the fuel level should be assembled with shellac, being careful not to get it on the end of the plug where it will come off and be carried by the fuel into one of the metering orifices. Headless screw plugs above the fuel level and all other threaded parts screwed into the bodies should have a compound of graphite and castor oil put on the threads.

Float Level

The float level on these carburettors should be $\frac{13}{32}$ in. below the parting surface and is dependent upon the thickness of the gasket under the needle valve seat. The level should be checked under the same conditions encountered in service as regards the fuel used and the fuel pressure or head at the carburettor. The levels are set by the manu-

facturers with a pressure at the carburettor of one-half pound per square inch (19 in. petrol at ·710), and this is recommended for setting the levels in actual use.

How to Correct the Level

If, after fitting new parts, the level is not correct, remove the needle valve seat and put in thicker gaskets to lower the level, and thinner gaskets to raise it. One-sixty-fourth inch change in gasket thickness will change the level approximately $\frac{5}{64}$ in.

NOTES ON BOOST PRESSURE CONTROL AND MIXTURE STRENGTH

NORMALLY aspirated engines, unless of the high-compression type, can be given full throttle at ground or sea level without the compression pressure and thereby the explosion pressure rising beyond safe limits. Induction-pipe pressure was therefore of little interest to the pilot except as some indication of power output. Only with mixture strength was he really concerned and this will be dealt with later. These normally aspirated engines steadily lost power as they climbed, due to the increasing rarefaction of the air and hence the amount of oxygen available to burn with the fuel.

"Blown Engines"

To counteract this steady loss of power, mechanical means were introduced to force additional air into the induction system of the engine so that the pressure in it remained at the ground-level figure. These devices were known as superchargers or blowers and to-day engines so fitted are commonly known as "blown engines." There is, however, a limit to the height to which a blower can sustain ground-level induction-pipe pressure and that height is known as rated height, critical altitude or full-throttle height. An engine in which the blower can sustain ground-level pressure to, say, 12,000 ft. is known as a 12,000-ft. engine. At this height the carburettor throttle is wide open and the power output falls as this height is exceeded until an altitude is reached beyond which the engine cannot lift the aeroplane any farther. This is known as the aeroplane's absolute ceiling.

"Gated" Throttle Lever

At 12,000 ft. the air density is only seven-tenths of that at sea-level, which gives some idea of the extra pressure necessary from the blower; it is equally obvious that with the blower working at sea level the quantity being forced into the induction system must be limited, or compression and explosion pressures will be reached that will damage the engine. To prevent this, the aeroplanes were fitted with a "gated" throttle lever, i.e. the quadrant in which it moved was fitted with a series of stops or "gates," each of which represented a safe throttle opening for some particular height. This was reasonably satisfactory for civil types,

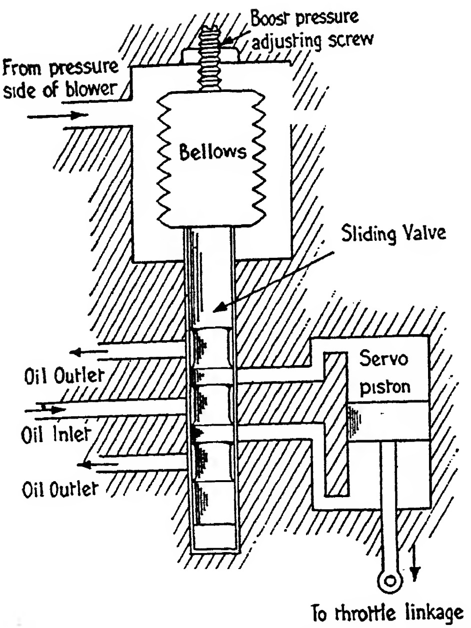


Fig. 1.—Essential features of a boost control

where the pilot had time to observe his instruments; but for military work, where aeroplanes changed altitude very rapidly and the pilot had a multitude of other duties, the gated throttle was unsatisfactory and engines were in consequence damaged.

Boost Control

Some mechanical device was sought that would remove from the pilot all responsibility for induction-pipe pressures and the first step in this direction was the invention of the induction pressure control, popularly known as a boost control. The linkage attached to this device was interposed between the pilot's throttle control and the carburettor throttle lever so that it took charge of the throttle opening if the pilot inadvertently pushed his throttle lever beyond a safe point for the altitude at which he was flying and the boost control was adjustable so that the maximum permissible pressure in the induction system could be varied according to the maker's designs. Boost controls have for some years been a standard fitting to all British supercharged engines and their use has now spread to the Continent and the U.S.A.

When "taking off," the pilot can open wide his throttle lever, knowing that the boost control will limit the carburettor throttle opening to a safe predetermined amount. As the aeroplane climbs, the boost control gradually opens the throttle to maintain a constant pressure in the induction system until at the engine's rated height the throttle is wide open. Above this height it can do no more, unless the aeroplane is dived under conditions in which the airscrew forces the engine revolutions to the point where the boost pressure rises above normal, in which case it intervenes and closes the throttle the required amount. As soon, however, as the aeroplane goes below rated height, the boost control once more becomes operative.

Essential Parts of a Boost Control

Fig. 1 shows diagrammatically the essential parts of a boost control. They consist of an airtight chamber connected to the pressure side of the

blower and a one-piece stack of barometric capsules fixed to the casing at one end and to a sliding valve at the other. Lands on the valve serve to control a high-pressure engine-oil supply to a servo piston, which piston controls the linkage between the pilot's throttle lever and the carburettor throttle lever. If the pressure in the induction system rises, this increase will be communicated to the capsule chamber and cause the bellows to shorten in length. This will lift the valve and thereby allow oil to enter the top side of the servo piston, causing it to move downwards. Conversely, if the blower pressure falls, the capsules will expand and push the valve downwards to allow oil to pass to the other side of the servo piston, thereby causing it to rise.

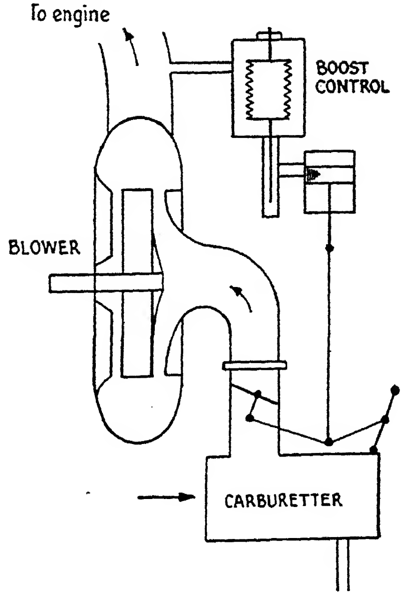


Fig. 2.—ONE FORM OF BOOST-CONTROL LINKAGE

As the servo piston controls the throttle opening, it will always correct any variation in boost pressure by altering the opening of the throttle the required amount. If for any reason such as change in engine load or speed, altitude or pilot's throttle lever position the induction (boost) pressure changes, the boost control will operate and bring its piston back to the position where it controls at the preset figure. The capsule will always settle down to a length where the lands on the valve are covering the ports leading to both ends of the servo piston. This is known as the "sensitive" position and is the position taken up when the engine is running steadily and with no variation in induction pressure.

Earlier Type of Boost-control Linkage

Fig. 2 shows in diagrammatic form an earlier type of boost-control linkage. It is obvious that any up or down movement of the servo piston will change the carburettor throttle opening, although the pilot's throttle lever may not be moved. Similarly any movement of the pilot's throttle lever and its effect on the throttle opening can be nullified by the movement of the servo piston.

Instances have occurred where linkage has been disturbed when the carburettor has been dismantled. After reassembling the carburettor, boost control and linkage, a check should be made as follows:

Put pilot's lever to "full open" position and when boost-control

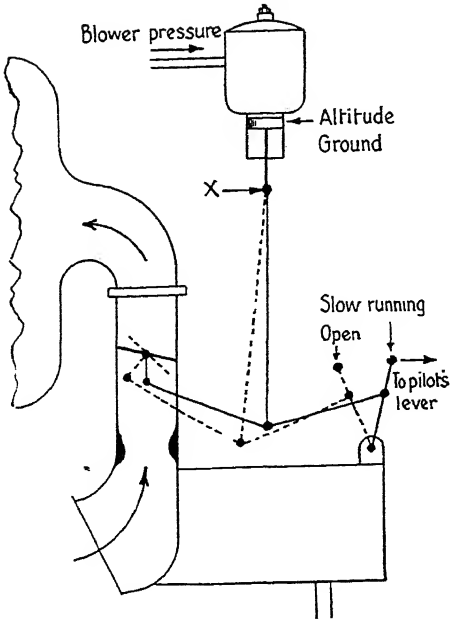


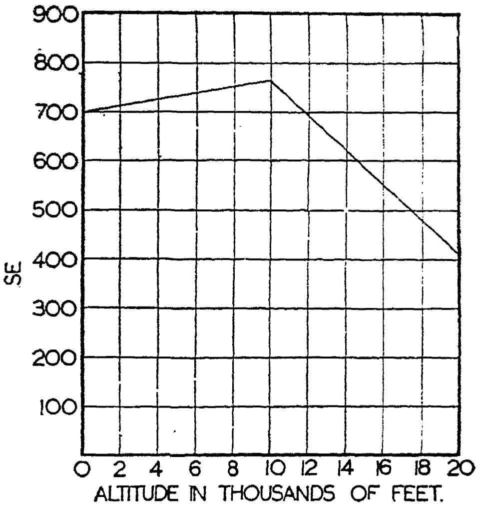
Fig. 3.—BOOST CONTROL IN SLOW-RUNNING POSITION

piston is pulled to the "altitude" position, the carburettor throttle should be wide open. If this is not so, then a mistake has been made in the assembly or adjustment of the linkage.

It has already been mentioned that one end of the capsule is fixed to the capsule chamber. This fixing is in the form of an adjusting screw and locknut by which the position of the capsule can be varied in the capsule chamber. Assume the engine to be running at ground level, with the servo piston holding the throttle to some definite angle and the induction pressure to a predetermined figure. The valve will be in the "sensitive" position and the servo piston stationary in some intermediate position. If the adjusting screw is moved so that the capsule and valve are moved downwards (Fig. 1), oil will pass to the lower side of the servo piston, causing it to rise and open the throttle somewhat. This will give a higher induction-pipe pressure, which in turn will compress the capsule, so that the valve once more will return to the "sensitive" position and the servo piston will remain stationary but in a new position.

The engine will now be running under higher boost-pressure conditions. Similarly, by raising the capsule bodily in the capsule chamber, the boost pressure can be lowered and the fixing screw becomes in effect a boost-pressure adjusting screw by which the engine makers can fix the maximum permissible pressure in the induction system.

In some engines, when hot, the oil pressure at slow running drops considerably from its normal working pressure, with a corresponding drop in pressure on the servo piston. Under such circumstances there is sometimes a delay in the movement of the piston when the pilot opens up his throttle lever, due to the fact that until the oil pressure builds up with the increase in engine revolutions the boost control remains inoperative. To remedy this a spring is added in such a way that it tends to bias the piston towards its slow-running position. In some cases it is an external one fixed to some convenient point on the linkage and in others it is inside the servo-piston cylinder.



4.—POWER-OUTPUT CURVE FOR AN ENGINE SUPERCHARGED TO 10,000 FT.

Fig. 3 shows the servo piston in the "slow-running" position and it will be seen that it has taken up the extreme altitude position, due to the fact that the low pressure in the induction system under these conditions is very similar to high-altitude conditions. As soon, however, as the pilot opens his throttle control, it will move away from that end and take up a position lower down the cylinder, the position being such that it holds and limits the induction pressure to the figure to which the control has been adjusted.

In Fig. 4 will be found a power-output curve for a 10,000-ft. engine fitted with a boost control. It will be noticed that although the induction pressure is being held constant from ground level to 10,000 ft., the power rises. This is due to the decreasing back pressure on the exhaust pipes and the better scavenging which results. Above 10,000 ft. the power drops steadily. The throttle is wide open, but the air density drops steadily.

In order that the oil in the boost control should be kept hot so that the boost control responds instantly to changes in boost pressure, it is found necessary to keep oil circulating past the valve and servo piston and to this end a very small hole is drilled through the piston. To make up the loss of oil through the hole and maintain the pressure on the piston, the valve must be slightly off the "sensitive" position and this state of affairs always occurs in actual practice. The hole varies from ½ to 1½ mm., but if made too large causes loss of power of the piston.

Boost Surge

Occasionally a boost-control piston will surge or hunt, causing the engine speed to rise and fall at regular intervals. This can invariably be cured by increasing the size of the leak hole in the piston and sometimes by putting a frictional damping device on one of the throttle linkage joints. Surging may be caused by any of the following:

(1) Air in the oil pipes.
(2) Intermittent slipping of the supercharger clutch.
(3) Blower surge.

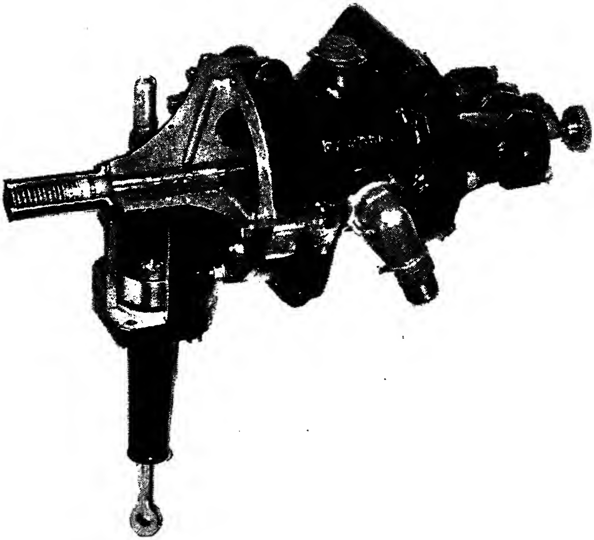


Fig. 5.—A VARIABLE-DATUM BOOST CONTROL CUT AWAY TO SHOW SERVO PISTON, OIL-CONTROL VALVE, OIL PASSAGES AND PISTON STOP

(4) Internal diameter of connecting pipe between blower and boost control too small, causing a lag in the transmission of changes in boost pressure.

(5) Excessive wear in linkage.

(6) Linkage tight in one position and loose in another.

Figs. 5 and 6 show a sectioned boost control. In this particular design the servo piston moves downwards for the altitude position. This is merely a question of the direction of the oilways in the boost control and the direction of movement is chosen to suit the general layout.

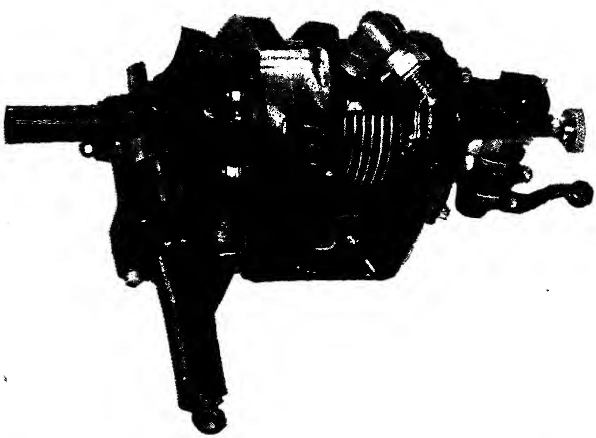


Fig. 6.—A VARIABLE-DATUM BOOST CONTROL CUT AWAY TO SHOW THE CAPSULE

To be seen also is the elbow containing the sharp-edged orifice.

Boost-control Adjustment: Rated Boost

The engine must first of all be warmed up to the correct temperature and the throttle control then opened up slowly, the boost-pressure gauge being carefully watched. In order to avoid any possible error, the boost-pressure gauge should always be checked for accuracy against a mercury column. If the pilot's throttle

control can be opened to the rated boost position without reaching the required boost pressure, then the boost-pressure adjusting screw should be turned slowly in a clockwise direction until the correct pressure is obtained. The screw should then be locked and sealed.

If, on the other hand, the required pressure is reached before the pilot's throttle control has reached the rated boost position, the boost-adjusting screw must be unscrewed until this opening can be given without exceeding the correct pressure.

There are two methods of describing boost pressure, one in pounds per square inch or kilograms per square centimetre and the other in inches or millimetres of mercury absolute. The former can be read on a pressure gauge or mercury column and the latter is the pressure in the induction system above or below normal atmospheric pressure, which is taken as 760 mm. of mercury (Hg) or 29·92 in. Hg. If, for example, the mercury column shows 860 mm., then there is a pressure in the induction system of 100 mm. above atmosphere. If it shows 700 mm., then there is a pressure of 60 mm. below atmosphere. The former is popularly known as plus boost and the latter minus boost, but in Great Britain the boost pressures are mostly given in pounds per square inch.

Throttle Curves

As an example, assume a 10,000-ft. engine in which normal boost at ground or sea level is obtained with a carburettor throttle opening of only 25°, the full available range of throttle opening being 75°. Let the pilot's throttle control be opened up from the slow-running position. The throttle will be opened mechanically via the linkage until it is 25° open. At this point the boost pressure will have risen to the figure at which the boost control (previously adjusted) takes charge and it will hold the carburettor throttle at a steady 25°, although the pilot moves his throttle control to the full-open position *or any intermediate position*, i.e. anywhere between 25° and 75° the same power prevails and the pilot's lever is "dead" in so far as it has any control over power output.

At or near ground level, therefore, if the pilot wants something less than full power, i.e. cruising without the power jet in action, he must close his throttle to an extent that closes the power-jet valve. In many carburettors the power jet is timed mechanically off the carburettor throttle, so that it will close at, say, in this instance, 20° throttle opening.

Let the aeroplane be flown up to 5,000 ft. Due to the rarefaction of the air, in order to maintain the ground-level power the boost control must open the throttle and this it does progressively as the aeroplane leaves the ground. At this level the required throttle opening can be presumed to have increased to 50° for full power. If the pilot wants to cruise economically, he cannot unless he closes the carburettor throttle to 20° to put the power jet out of action, an opening much too small for

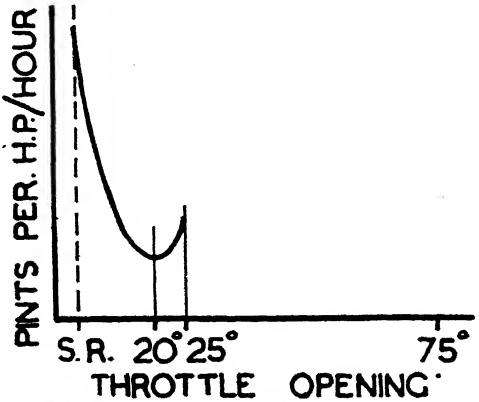


Fig. 7.—THROTTLE CURVE AT GROUND LEVEL

Power jet cut out at 20°.

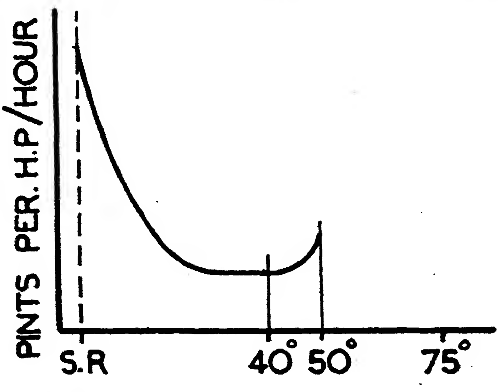


Fig. 8.—THROTTLE CURVE AT 5,000 FT.

Power jet cut out at 40°.

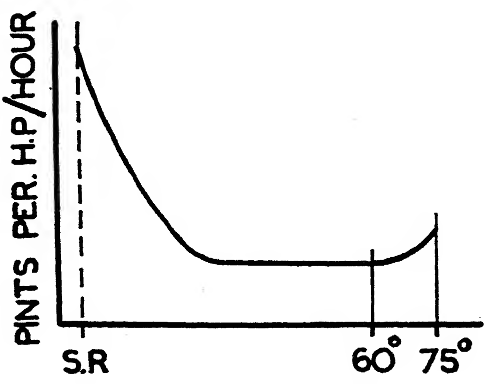


Fig. 9.—THROTTLE CURVE AT 10,000 FT.

Power jet cut out at 60°.

that altitude. Actually a closure from 50° to 40° is approximately the movement desirable. Similarly, at 10,000 ft. the rated height, where full power means full-open throttle (75°), it is again impossible to close the throttle, say, 20° and cut out the power jet. It is obvious, therefore, that at every altitude between ground level and rated height, a difference in the timing of the power-jet action must exist, and this is now accomplished and known as "traversing the power jet."

Figs. 7, 8 and 9 show throttle curves for a 10,000-ft. engine at ground level, 5,000 ft. and 10,000 ft. (rated height), the difference between mixture strength at part throttle (cruising) and at full power being exaggerated for the sake of clearness.

Fig. 7 shows the throttle curve at ground level with 25° throttle opening for full power and 20° for maximum cruising with the power jet out of action. Fig. 8 shows the throttle curve at 5,000 ft., 50° representing the full-power throttle opening and 40° the maximum cruising opening. Fig. 9 shows the throttle curve at rated height. Full power is given with full throttle opening 75°, closing the throttle to 60° giving maximum cruising with the power-jet valve closed.

An actual instance can be cited where a certain Continental aero-engine is fitted with a carburettor in which the power jet is timed mechanically off the carburettor throttle. The engine is medium supercharged and has a ground-level throttle opening for take-off of 30° out of a total of 75°. The power jet is timed to come into action at 27° throttle opening, so that only near the ground can the pilot close his throttle slightly and come on to a cruising mixture strength. At normal operational heights, where the carburettor throttle is fully or almost fully open, a throttle opening of 27° is too small for cruising purposes and the power jet is therefore feeding fuel the whole time. To obtain a reasonable fuel consumption, this means that the pilot or rather his engineer has to use continuously the hand-operated mixture control, in conjunction with an exhaust gas analyser. It is obvious that this is an impossible state of affairs with military types although possible with large civil aeroplanes, where a person is allocated specially to deal with this problem.

It will be seen, therefore, that every altitude between ground level and rated height requires its own different power-jet timing, and this can only be accomplished by timing the power-jet operation off the *pilot's throttle lever and not the carburettor throttle,* but entirely in conjunction with a special type of boost control, a description of which follows.

Eliminating Lost Motion in Pilot's Throttle Lever

With the idea of eliminating the lost motion in the pilot's throttle lever, which is a maximum at ground level and decreases as the aeroplane climbs to the engine's rated height, a device was patented which, while solving this problem, incidentally brought with it several other advantages. The manner in which it works is best described as follows:

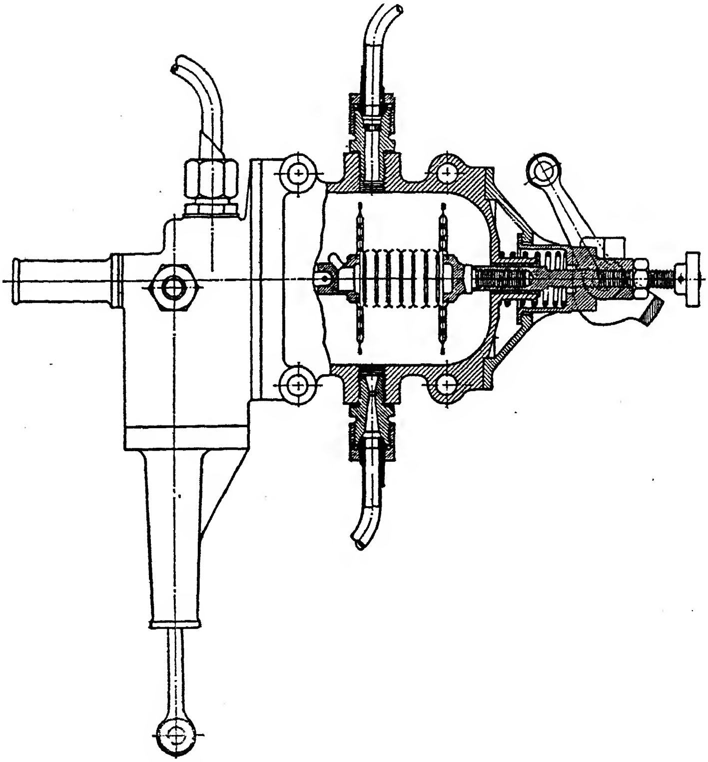


Fig. 10.—SECTION THROUGH VARIABLE-DATUM BOOST CONTROL
Only two of the eight capsules are drawn.

Let it be assumed that an engine is running, on which a boost control has been adjusted to control at rated boost and it is at this boost pressure that the engine is running with the pilot's throttle lever fully opened, i.e. with the power jet in action. Assume also that the pilot's lever is slowly and progressively closed to the slow-running position and that this is accompanied by the boost-pressure adjusting screw being unscrewed so that the boost pressure is progressively lowered. Then imagine the exact reversal of this action, a progressive opening of the pilot's throttle lever with the boost-pressure adjusting screw gradually screwed down to raise the boost pressure to its original rated boost figure.

Mechanically, this method of raising and lowering the boost pressure is cumbersome and so difficult to operate successfully, but if a cam controlled by *the pilot's throttle lever* is used to raise and lower the capsule assembly, the same result can be obtained. A boost control so constructed is known as a variable-datum boost control. With such an arrangement it is obvious that anywhere between ground level and rated

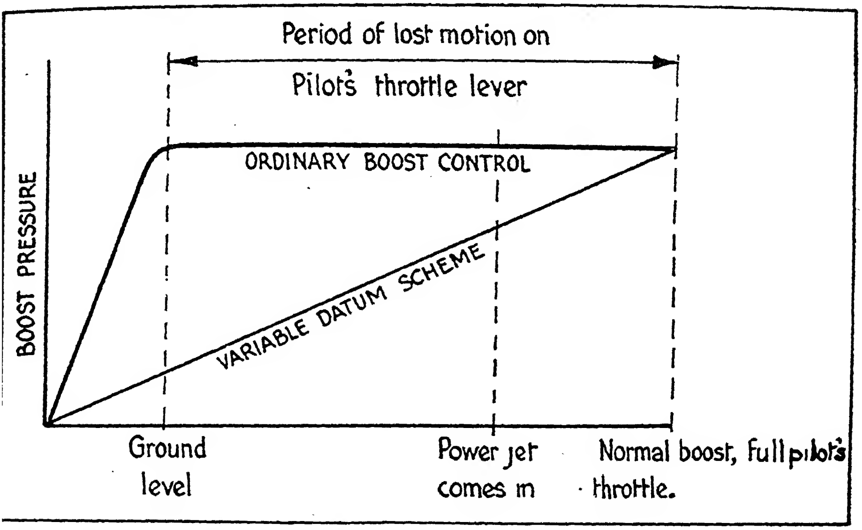


Fig. 11.—DIFFERENCE BETWEEN BOOST-PRESSURE CURVES OF AN ORDINARY AND A VARIABLE-DATUM BOOST CONTROL

height full boost can be obtained only with the pilot's throttle lever fully opened and not at several intermediate positions as with other types of boost controls. Further, if the power jet is operated by the pilot's throttle lever, it now becomes impossible to obtain full power anywhere between ground level and rated height without having the power jet in action and as the boost pressure rises and falls strictly *pro rata* with the pilot's lever movement, the control of engine-power output becomes as smooth and regular as a non-supercharged engine at or near ground level.

Fig. 10 shows a section through a variable-datum boost control and Fig. 11 shows the difference between the boost-pressure curves for various pilot's lever movements for the ordinary boost control and one of the variable-datum type. It will be seen that with the ordinary type, at ground level, the boost pressure rises rapidly for a small pilot's lever movement at ground level and then remains at a steady figure. This makes the exact control of engine speed very difficult near ground level and this is particularly marked during formation flying, where a small movement of the pilot's throttle lever can make large differences in power output. The curves also show how with the old method full power can be obtained without the power jet in action, the reverse of what can happen with the variable-datum method.

On further inspection of the curves it will be seen that with the variable-datum method, at any height up to rated height, the pilot must open his throttle fully to obtain full power, but he can always partly close his throttle and put the power jet out of action for economical

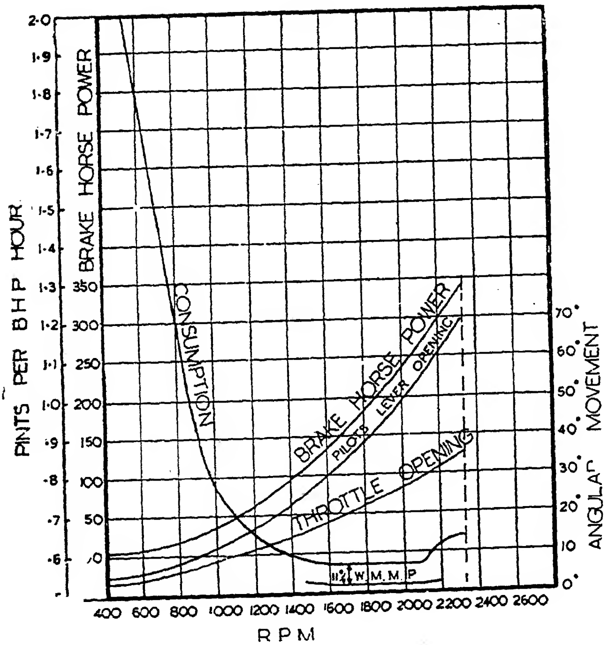


Fig. 12.—ENGINE-TEST CURVES WITH VARIABLE-DATUM BOOST CONTROL

cruising. In addition, up to rated height, any given position of his throttle lever will always ensure the same boost pressure.

Fig. 12 shows dynamometer test curves of a well-known engine supercharged to about 6,000 ft. and fitted with a variable-datum boost control. It will be seen how closely in shape are the curves for brake-horse-power and pilot's throttle-lever movement. The carburettor throttle opening at ground level is 35°, while the pilot's lever opening is 70°; but as the aeroplane climbs to rated height the throttle opening will gradually increase until at rated height it is also 70° open. The short and lowest curve is the one for weakest mixture for maximum power (popularly known as W.M.M.P.) and in this particular case the carburettor is tuned to be 11 per cent. richer than W.M.M.P. to ensure safe temperatures.

Ignition Timing

This is intimately connected with boost pressure and as up to rated height the position of the pilot's throttle lever always gives a definite value for the boost pressure, it is possible and advisable to control the ignition timing by the pilot's lever. By means of suitable links and cams, the ignition timing can be retarded for starting and slow running, advanced rapidly for economical cruising, retarded slightly for normal boost and further retarded during take-off, when temporarily a larger throttle opening is given.

Another method is that in which magnetos having two contact breakers are used, one timed early for advanced ignition and the other timed later for retarded ignition, the choice of either being obtained by a simple electrical switch operated by the pilot's throttle lever.

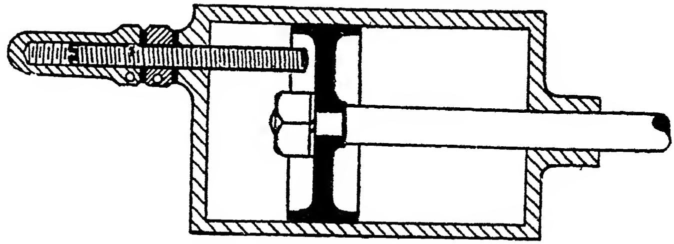


Fig. 13.—Externally adjustable boost-control piston stop

This requires very little mechanical effort to operate and in conjunction with a centrifugal advance and retard gives an approximately correct advance and retard curve. The control of hot and cold air can also be made by the pilot's throttle lever, hot air being supplied during slow running and cruising and cold air during full-power conditions, an override being used to obtain hot air with full power when atmospheric conditions are such that freezing may occur in the induction system and carburettor.

Boost-control Piston Stop

It has previously been explained how the boost-control piston takes up a position somewhere between the two extreme directions to which it can move when the adjusting screw is set to give rated boost at ground level. From the pilot's point of view it is important that should for any reason the oil pressure drop to a low figure or fail altogether, the piston cannot move to an extent that would close the throttle too far for the aeroplane to fly safely. To obviate such a predicament, a stop is provided that prevents the piston moving towards its "ground" position an amount giving less than about nine-tenths full power.

On earlier boost controls this consisted of a pin riveted to the piston, which bottomed on the cylinder cover, the pin being filed to the correct length during the engine test. This entailed partly dismantling the control and that type of stop is now replaced by one adjustable from outside, it consisting of a headless screw, locknut and oil-sealing cap.

With the engine running steadily at rated boost, the screw is screwed in until it just touches the piston and is then withdrawn about $\frac{1}{16}$ in. If the boost-control piston is now pushed hard against it, the fall in power should be not more than about 10 per cent. Should this not be the case, the screw is readjusted until its proper setting is found and then locked in position, the cap put on and the tabwasher bent into place. Fig. 13 shows such a boost-control stop, which can also be seen externally in Fig. 5.

Temporary Take-off Power

Due to the restricted throttle opening of supercharged engines at ground level, such engines (compared with naturally aspirated ones) are at a disadvantage. It has been found, however, that for a short period

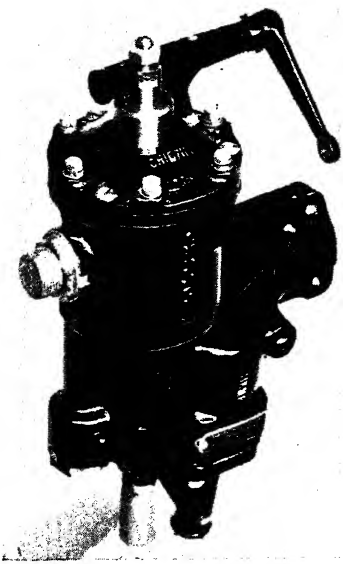


Fig. 14.—Boost control with mechanical override

15–20 per cent. increased power may be taken from the engine provided additional fuel is used. This fuel acts as an internal coolant for the cylinders and prevents the detonation that would inevitably occur when the throttle was given increased opening for take-off purposes. Additional power for take-off is of paramount importance to the pilot, as it shortens the take-off run before the aeroplane becomes "unstuck" and enables it to climb at a steeper angle to clear possible obstructions surrounding the aerodrome, thereby contributing to general safety. Having climbed to a safe altitude, the pilot can then reduce the power to a normal safe continuous output.

As the boost control has been set to prevent the induction pressure exceeding a safe degree, it has to be compelled to give a larger throttle opening for take-off purposes. This is known as overriding the boost control and can be accomplished in two ways, one mechanically and the other by an air leak to the capsule chamber. It is obvious that increased power for take-off could be obtained by screwing down the adjusting screw, but as this is set and sealed on the ground to control at rated boost and would have to be reset in mid-air, this method is not feasible. Instead, a forked lever is fitted to the boost control by means of which the pilot can depress the whole boost capsule assembly an amount fixed by an adjustable screw. The pilot's lever on the carburettor controlling this override lever also controls the additional fuel supply, there being an enrichment jet and a valve built into the carburettor which is timed to open rather earlier than the override device in order that the additional fuel shall reach the engine cylinders before the boost pressure goes up. If the engine is fitted with a variable-pitch airscrew, the latter, in combination with a temporary increase in power, enables aeroplanes to take off with heavier loads and in more confined spaces. Fig. 14 shows a mechanical boost override.

Air-leak Boost Override

Normally the capsule chamber of the boost control is sealed except for the connection to the pressure side of the blower. Assume the engine to be running at normal boost and with a certain pressure in the capsule chamber, e.g. + 2 lb. per square inch above atmospheric pressure.

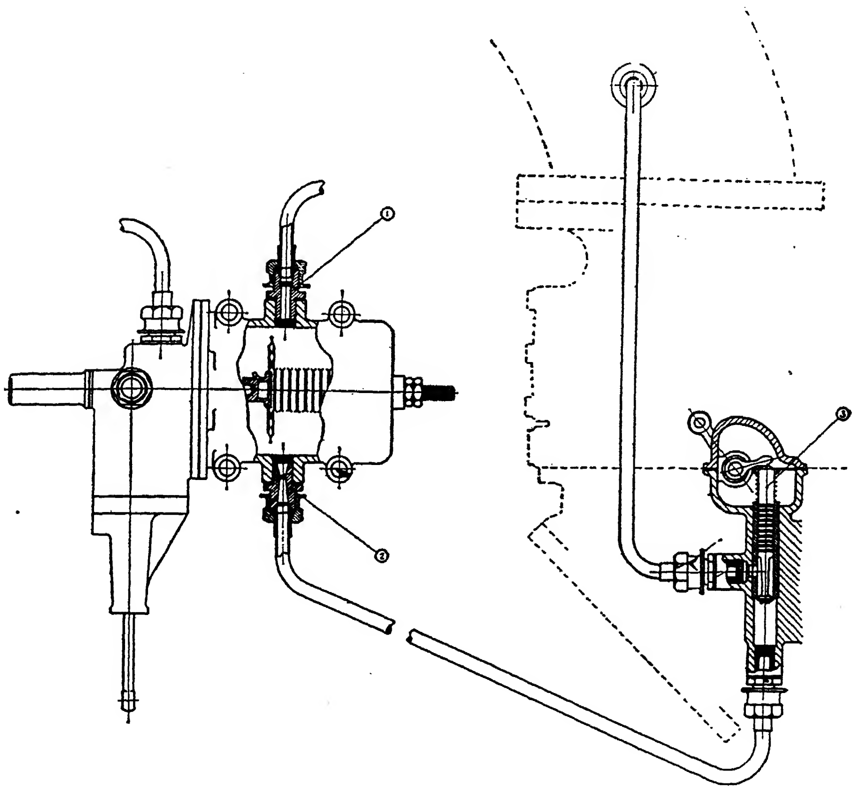


Fig. 15.—AIR-LEAK OVERRIDE CONNECTIONS

If now a leak-hole is placed in the capsule chamber, the pressure in it will fall and this will be followed in turn by an expansion of the capsule and a movement of the oil-control valve. The servo piston will then move to open the throttle until the pressure increases sufficiently to compress the capsule back to the position where the valve once more assumes its so-called "sensitive" position. The piston then comes to rest and holds the boost pressure steady at a new value, the increased boost pressure being of course accompanied by increased power.

In order to ensure that the same degree of leakage is obtained on every occasion, irrespective of variations of temperature, the leak is in the form of a valve built into the carburettor, which valve is again coupled to the enrichment jet valve and timed to come into action slightly after the latter, thereby ensuring that the richer mixture is in the cylinders before the boost pressure goes up. In addition, this override valve communicates with the *suction* side of the blower, thereby forming a complete circuit, but with the following modifications. In

the pressure side of the circuit and close to the capsule chamber is put a restriction of the "thin plate" type and on the outlet or return side is fixed a venturi, the combination of this type of air jet and venturi giving a constant pressure drop across the capsule chamber whenever the override valve is opened. By adjusting the relative sizes of the air jet to the venturi throat, the pressure drop can be varied and thereby the increase in take-off boost.

Fig. 15 shows diagrammatically an air-leak override to a boost control. It is important never to alter the size of the venturi once it is fixed by the makers. To ensure that every venturi is identical in characteristics they are "flowed" on a jet-calibrating machine and the flow marked in cubic centimetres per minute, so that engines of any particular type in series production shall have equal increases in boost pressure for take-off purposes.

Adjustment for Take-off Boost Pressure (T.O.B.)

If when the boost override valve is opened the increase in boost is too small, it is a sign that (in the air-leak type) the sharp-edged orifice is too large and a smaller one should be fitted. Conversely, if the take-off boost pressure is too high, the orifice has to be enlarged, but this should be done very gradually, as a small difference in the diameter of the hole makes a marked difference in boost pressure.

Mixture Strength

Mixture strength is intimately connected with boost pressure, i.e. power output. The higher the power output the richer must be the mixture and it is for this reason that, ignoring slow running and very low power, there are three different fuel/air ratios in general use: one for economical cruising, a second for normal full power (rated boost) and a third for take-off conditions. This is further complicated by the fact that for cruising and full power the mixture must be correctly weakened as the aeroplane gains height. Until recently the control of mixture strength lay in the hands of the pilot, in that he was given control of the carburettor mixture valve—to be used at his own discretion—which varied widely according to his experience and the degree of distraction by other duties. Fuel consumptions between similar aeroplanes flying the same distance under identical conditions frequently vary as much as 50 per cent., but these large variations have to-day become negatived by the introduction of automatic mixture controls, the type in quantity production in Great Britain being the two-stage type known as the Hobson-Penn.

The unnecessarily heavy fuel consumptions were largely due to the fact that the pilot was aware that very weak mixtures caused high temperatures and danger of seizure and burnt-out valves and he therefore erred on the rich side as a precautionary method. Whilst on short flights this, apart from the cost of the fuel wasted, was not of great

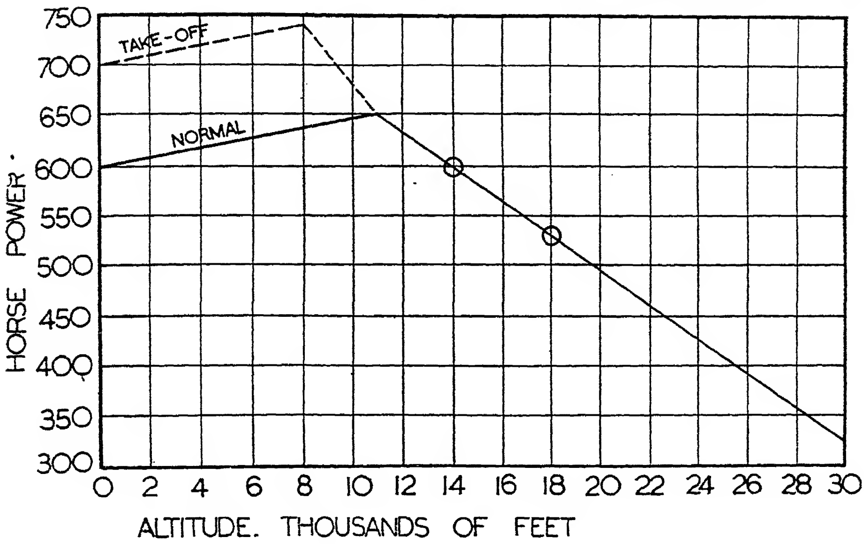


Fig. 16.—NORMAL AND TAKE-OFF POWER CURVES FOR 11,000-FT. ENGINE

account; but on very long flights, due to the load carried, fuel consumption is of paramount importance, as the load consists of the crew, fuel and the payload. It is obvious that the less fuel to be carried the greater can be the payload, which in the case of military types means weight of bombs or armament.

Weak Mixture with Full Throttle

If Fig. 16 is referred to, it will be seen that the power output increases steadily up to the engine's rated height (in this case 11,000 ft.) and then falls steadily above this altitude. It will also be seen that at 14,000 ft. the power output equals the ground-level output of 600 h.p. and that at 18,000 ft. the power is equivalent to a *ground-level cruising output*, the carburettor throttle still being wide open to obtain the maximum power available at that altitude. It is obvious that the power jet will be in action, but due to the reduced power output quite unnecessary. Means must therefore be provided so that the power jet can be put out of action under these conditions, as it is merely wasting fuel. This is done in conjunction with what is known as a three-phase boost control, which will be described in detail when automatic mixture controls have been described.

Types of Mixture Control

Many ideas for controlling fuel flow to the engine under altitude conditions have been put into practice, some good and others unsatisfactory.

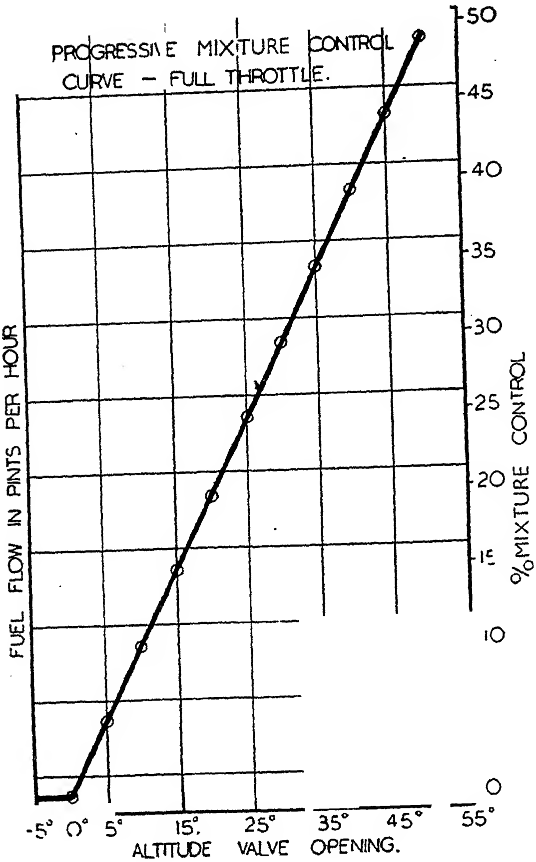


Fig. 17.—A TYPICAL MIXTURE-CONTROL CURVE OF A CLAUDEL-HOBSON AEROPLANE CARBURETTOR

It will be noticed that there is a 5° overlap of the valve in the closed (rich) position.

Putting a depression on the inside of the float chamber by connecting it via an adjustable valve to the throttle bore is one method, but it suffers from the defect that the suction alters with varying throttle openings. This means that if the pilot alters his throttle opening at any particular altitude, he will probably have to alter his mixture-adjusting valve.

One of the best and most consistent is the type in which air taken from the pressure balance in the carburettor air intake is allowed to leak into the passage which discharges the fuel into the airstream, thereby reducing the "suction" placed on the jet system. By increasing or decreasing the amount of air, the fuel discharge can be varied accurately over a wide range.

The percentage reduction in mixture strength required by modern aero engines is at least 40 per cent. and it is obvious that a range of control of this extent can, in the hands of a careless or inexperienced pilot, cause grave risk of damage to the engine or, on the other hand, gross wastage of fuel. It is for this reason, therefore, that numerous devices have been invented with the idea of taking the control of mixture strength away from the pilot and making it purely automatic.

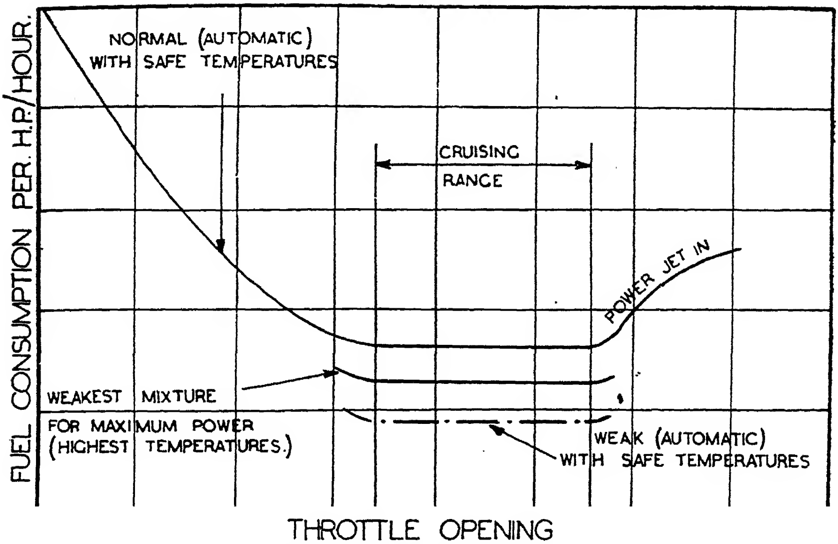


Fig. 18.—" NORMAL AUTOMATIC," W.M.M.P. AND " WEAK AUTOMATIC " CURVES

Carburettor Characteristics for Automatic Mixture Control

Before an automatic mixture control can be successfully applied, the carburettor must conform to certain details in its performance and characteristics. They are as follows :

(1) The altitude valve must give a " straight-line " curve, i.e. equal and progressive movements of the altitude valve must give equal and progressive weakening of the mixture (see Fig. 17) ;

(2) Opening of the altitude valve must drop the throttle curve so that each new position is parallel to the normal curve ;

(3) The carburettor must be capable of being tuned to give a horizontal position to the cruising portion of the throttle curve (see Fig. 18) ;

(4) Changes in throttle opening must not affect the percentage altitude control given by any set position of the altitude valve.

The deficiency of so many automatic mixture controls was that they took the mixture curve near to or into the W.M.M.P. (Weakest Mixture for Maximum Power) position, with its attendant dangers. The British Hobson-Penn model, however, was based upon an entirely new idea. Formerly the mixture strength during engine tests was always kept sufficiently on the rich side of W.M.M.P. to be safe, but it was eventually discovered that if mixtures were used sufficiently weak beyond W.M.M.P. to cause a drop in engine revolutions, temperatures also fell to a safe point and that engines could therefore be run on exceedingly economical mixture strengths at somewhat reduced revolutions. The Hobson-Penn control was therefore designed so that the pilot has only two main

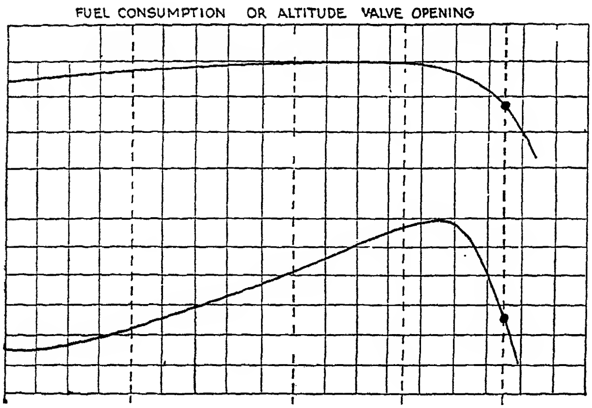


Fig. 19.—CURVES OF MIXTURE STRENGTHS AND CYLINDER TEMPERATURES

C, weakest mixture for maximum power ; *B*, normal power mixture ("Normal Automatic") ; *D*, cruising mixture strength, giving drop in revs. with safe drop in temperature and steady running ("Weak Automatic") ; *A*, 12 per cent. richer than *B* for take-off boost.

ranges of mixture, one for maximum power and acceleration (approximately 10 per cent. richer than W.M.M.P.) and another sufficiently weak below W.M.M.P. for maximum economy. The mechanism of this control opens and shuts the altitude valve of the carburettor strictly according to altitude, so that the pilot's cockpit mixture lever has two settings only, "Normal" and "Weak," the device giving him without further attention correct mixture strength with either setting of his lever from sea level to the aeroplane ceiling and not merely to some specified height, such as rated height, above which manual control of the mixture strength becomes necessary.

The average drop in engine revolutions below W.M.M.P. varies between $2\frac{1}{2}$ and 5 per cent., but averages about 3 per cent. and must not be taken so low that the engine becomes "rough" or unsteady. Advancing the ignition a further 10° or 12° throughout the cruising range is of considerable advantage and will enable an engine which would be very unsteady to run smoothly on ultra-weak mixture. Fig. 19 shows curves for mixture strength and cylinder temperatures. In this illustration *C* shows the W.M.M.P. point, *B* the normal mixture strength, *D* the "economical cruising with safe temperatures" mixture strength and *A* the extra-rich mixture necessary when the boost control is overridden for take-off purposes.

Slow-running System and Mixture Control

As already mentioned, any set opening of the altitude valve should drop the throttle curve in a strictly parallel fashion. Fig. 20 shows how fuel is wasted if this is not so. Due to the fact that mixture-control curves cannot be successfully taken on an engine test bed at ground level unless very large and costly plant is used to simulate the drop in

back pressure on the exhaust pipes, as well as the lowered air temperature, some confusion has occurred by people attempting to do this. The complaint is that the curve does not drop in a parallel fashion and this can be explained as follows :

On highly supercharged engines, the throttle opening on the ground may be only 16° or 18° out of a total opening of 70° or 75°. This means that the slow-running system, which is not affected by mixture control, has a powerful effect on the throttle curve due to the small opening. As, however, the aeroplane climbs from the ground and the boost control steadily opens the throttle, the effect of the slow-running system diminishes until at a given altitude the horizontal portion is unaffected by it. Fig. 21 shows diagrammatically this effect, which is one that is so often overlooked.

The Hobson-Penn Automatic Mixture Control is shown diagrammatically in Fig. 22 and two further illustrations are given in Figs. 23 and 24, in which certain parts have been cut away to show the internal construction and passages. It consists of a chamber open to the atmosphere and containing a stack of barometric capsules in a housing connected to a valve controlling oil supply to a servo piston very similar in construction to a boost control.

There are two main differences, however. One is a rotatable sleeve situated round the valve and having two sets of oil holes

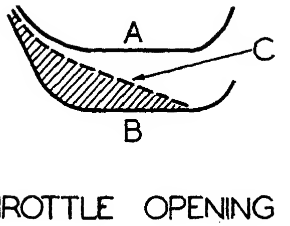


Fig. 20.—SHOWING HOW FUEL IS WASTED IF THE THROTTLE CURVE DOES NOT DROP PARALLEL TO THE NORMAL CURVE WHEN THE MIXTURE CONTROL IS OPERATED

A is the normal curve and *B* the correct one. *C* shows a defective curve, the shaded portion representing wasted fuel throughout the cruising range.

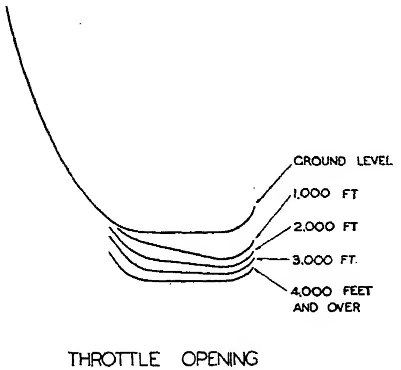


Fig. 21.—SHOWING THE EFFECT OF THE SLOW-RUNNING SYSTEM ON ALTITUDE CURVES TAKEN ON THE ENGINE TEST BED

The figures are obviously for explanatory purposes only, as they depend on the engine's rated height.

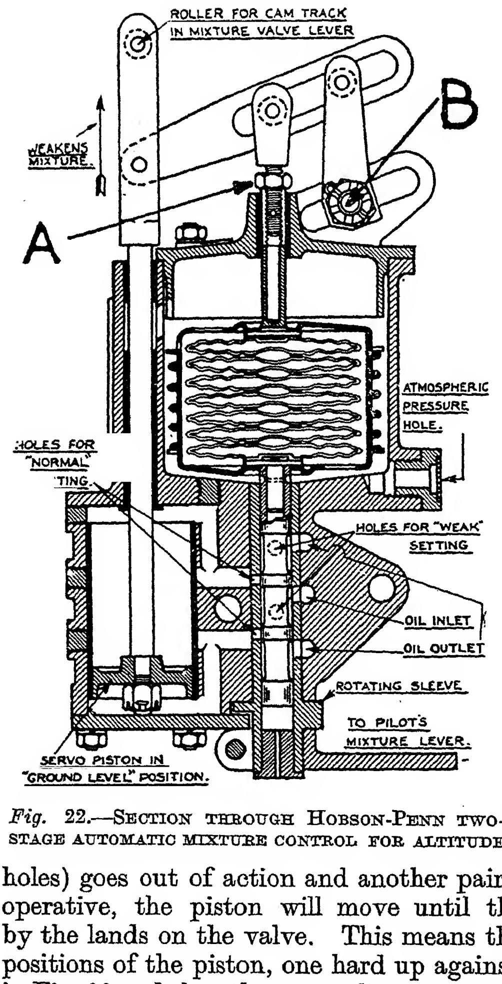


Fig. 22.—Section through Hobson-Penn two-stage automatic mixture control for altitude

at different heights and the other the fact that the opposite end of the capsule is anchored to the servo-piston rod by a sliding link, so that movement of the piston also moves the capsule and valve assembly. This means that any partial expansion or contraction of the capsules due to a change in altitude will be accompanied by a partial and not complete movement of the piston. The latter will move only so long as the oil ports are open and the movement of the piston tends to close them off, the piston coming to a standstill until a further change in length of the capsule assembly occurs.

Rotating Sleeves

If the piston always moves the valve to close off the ports, it is obvious that if the sleeve is rotated so that one pair of ports (oil-feed holes) goes out of action and another pair at a different height becomes operative, the piston will move until the second pair is covered up by the lands on the valve. This means that there are two ground-level positions of the piston, one hard up against the cylinder cover as shown in Fig. 22 and the other some distance away. These two positions represent respectively the "ground-level normal" and the "ground-level weak" setting of the altitude valve to which the servo piston is coupled. By using sleeves in which the spacing of the two sets of oilways vary, any desired difference in the position of the piston at ground level between "normal" and "weak" can be obtained. Such sleeves are lettered *A*, *B*, *C*, *D* and *E*, the *A* sleeve giving the smallest difference and the *E* sleeve the greatest.

Flight Tests

To obtain all the correct data, the aircraft engine must be flown at various heights and power outputs. From these the amount of

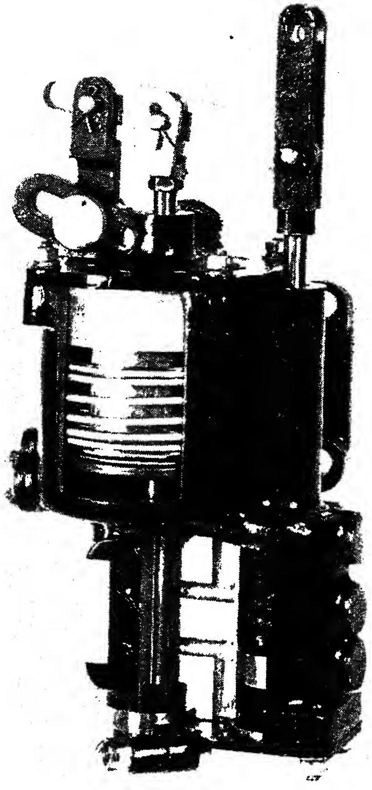


Fig. 23.—HOBSON-PENN TWO-STAGE AUTOMATIC MIXTURE CONTROL FOR ALTITUDE

Sectioned to show the oil-ways, servo piston, capsule container with spring and rotating sleeve.

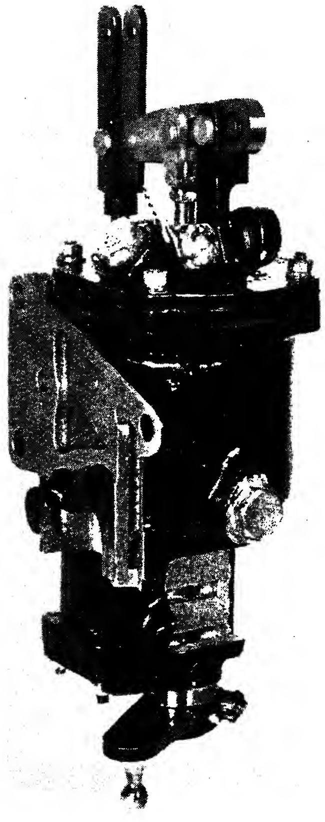


Fig. 24.—HOBSON-PENN TWO-STAGE AUTOMATIC MIXTURE CONTROL FOR ALTITUDE

Showing oil passages and gauze-covered opening to the capsule chamber.

weakening necessary to obtain "weak automatic" conditions can be observed and the necessary cam-track lever designed. The latter is a slotted lever fastened to the carburettor altitude valve, the roller on the servo-piston rod running in the cam-track slot. The shape of the slot varies with different types of engines and correlates the inherent carburettor and automatic mixture control characteristics. Fig. 25 shows one type of cam-track lever. It will be seen, therefore, that with the rotating sleeve in the "normal automatic" position (previously called "rich automatic"), the piston will start at ground level in the position shown in Fig. 22 and move to a position approximately half-way up the cylinder as the aeroplane climbs. With the sleeve turned to the

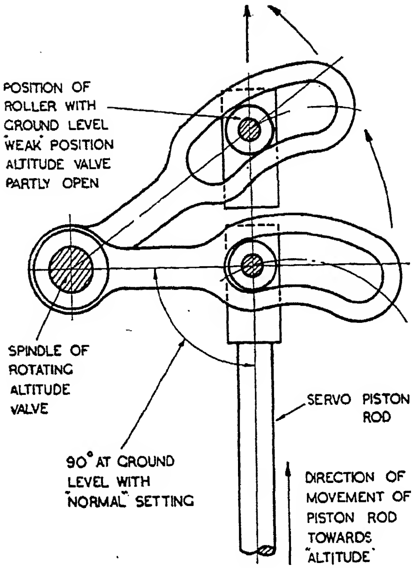


Fig. 25.—CAM-TRACK LEVER AT GROUND LEVEL "NORMAL" AND GROUND LEVEL "WEAK"

"weak automatic" setting, the piston will start some little way down the cylinder at ground level, i.e. with the altitude valve partly open and travel a greater distance at altitude than with the "normal" setting. Fig. 25 also shows this movement.

The final calibration of this device entails the use of a special test rig and specially trained mechanics. It is definitely dangerous for any other person to attempt to alter any of the adjustments, particularly the two locknuts marked *A* and *B* shown in Fig. 22. These are soldered before leaving the makers' works and should they ever be disturbed the instrument must on no account be used until it has been recalibrated by the makers or serious engine damage can occur.

Single-stage Automatic Mixture Controls

Instances have occurred where capsules in the form of a bellows or concertina have fractured due to vibration, with the result that the mixture strength went immediately to "full weak," causing the engine to cut out long before the pilot landed. To avoid this dilemma the bellows were then spring loaded in the opposite direction, with the result that if breakage occurred the mixture went "full rich," badly curtailing the range of the aeroplane and making flight at high altitude impossible.

Advantages of the Two-stage Type

For this reason the Hobson-Penn control uses seven separate capsules held lightly in contact in a spring-loaded cage. Should a leak occur in any one capsule, its expansion would cause only a slight proportional decrease in mixture strength and if two or more failed, the pilot can always turn over to the "normal" setting without seriously curtailing the range of his aeroplane, owing to the fact that the "normal" setting was slightly weakened as the result of the fractured capsules. Actually, owing to the careful selection of material, etc., no instance is on record of the failure of a capsule.

A further safety device lies in the flanged construction of the capsule cage. Should the valve stick through the presence of dirt in the oil,

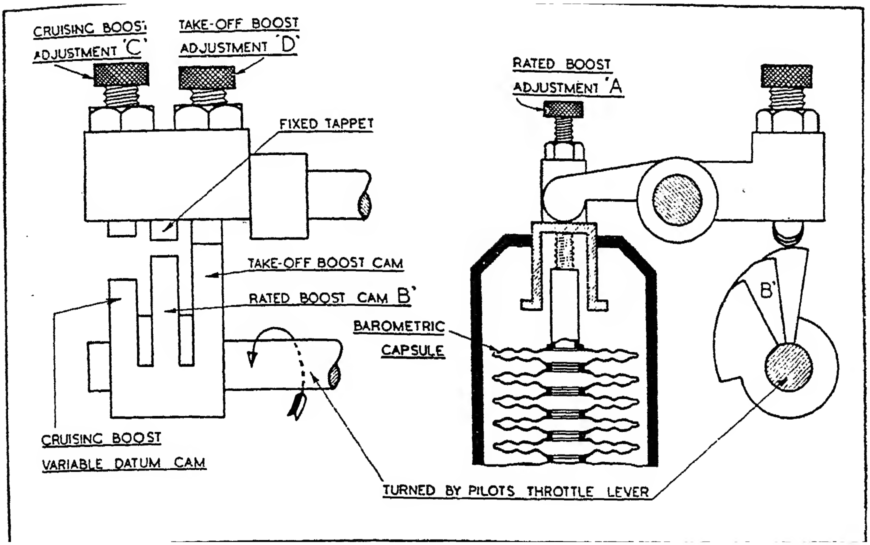


Fig. 26.—Three-phase boost control shown diagrammatically
A return spring (not shown) keeps all the parts in contact.

the piston moves until the spring becomes coil-bound, when any further movement pulls the whole cage and valve assembly bodily with it, thereby "unsticking" the valve, after which the piston returns to the position appropriate to the engine's height above ground level. The piston does not have a small hole drilled through it, as its movement is relatively slow when compared with a boost-control piston.

Multi-stage Boost Controls

The introduction of the variable-datum boost control gave the pilot a control of boost pressure entirely different from that which he had been used to with supercharged engines fitted with earlier models of boost controls. There was no lost motion in his throttle lever and he could always rely on getting a predetermined boost pressure (up to rated height) by putting his throttle lever to any given position. There were, however, three definite boost pressures which it was considered desirable always to "locate" in his cockpit throttle control. These were maximum cruising boost (power jet *not* in action), rated boost (power jet in action) and take-off boost (power and enrichment jets in action).

The variable-datum scheme was therefore modified, so that instead of a single cam giving a simple variable-datum action, three separate cams were incorporated, each with its own range of boost pressure.

The single variable-datum cam was replaced by three cams of different

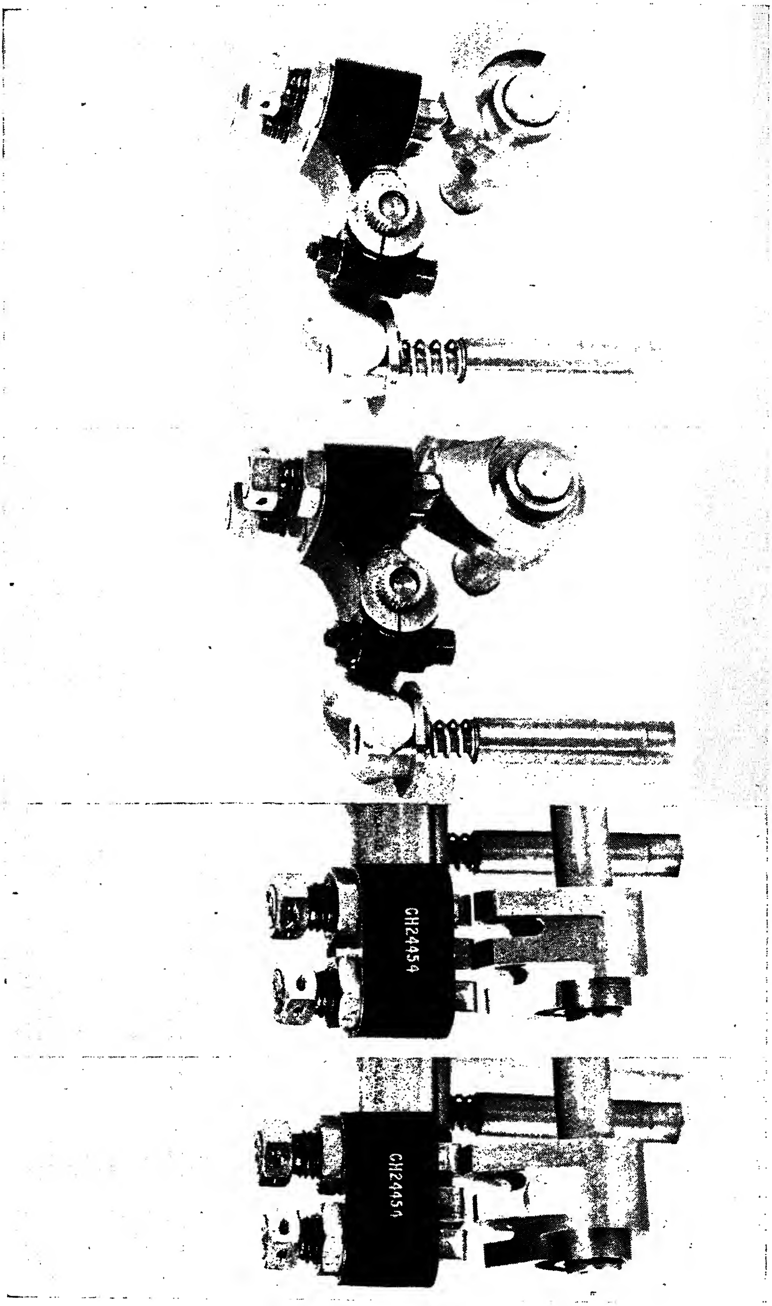


Fig. 26A.—ACTUAL THREE-PHASE BOOST-CONTROL PARTS

(Left to right) Take-off boost, rated boost, maximum cruising boost, slow running. The rated boost adjustment is not shown.

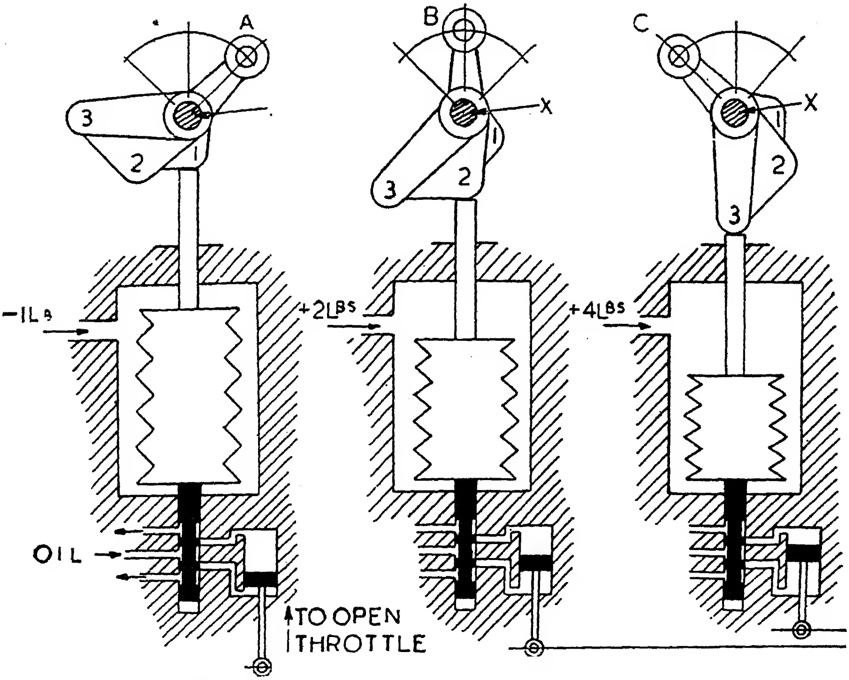


Fig. 27.—Varying compression of the boost-control capsule under three different boost pressures

The valve comes to rest always in the sensitive position.

lift and angular spacing, each cam having its own tappet for shifting the boost capsule assembly.

These cams are located on the shaft carrying the pilot's throttle lever on the carburettor and are so angularly spaced that the first cam to operate is the one that moves the capsule assembly from the slow-running to the maximum cruising boost position, the second from maximum cruising to rated boost and the third from rated boost to take-off boost. This is shown diagrammatically in Figs. 26 and 26A.

In order to ensure that these definite boost pressures can always be accurately " located " by the pilot's throttle lever, flats are put on the high-lift portion of each cam, to enable the pilot's cockpit throttle lever to be synchronised exactly with the carburettor.

Fig. 27 shows diagrammatically how, when the capsule and valve are moved bodily downwards, the boost pressure rises and compresses the capsule back to a length where the valve reaches its " sensitive " position. In this illustration the cams (pivoting on spindle x) are not shown with a variable-datum contour. Position of pilot's lever is as follows: *A*

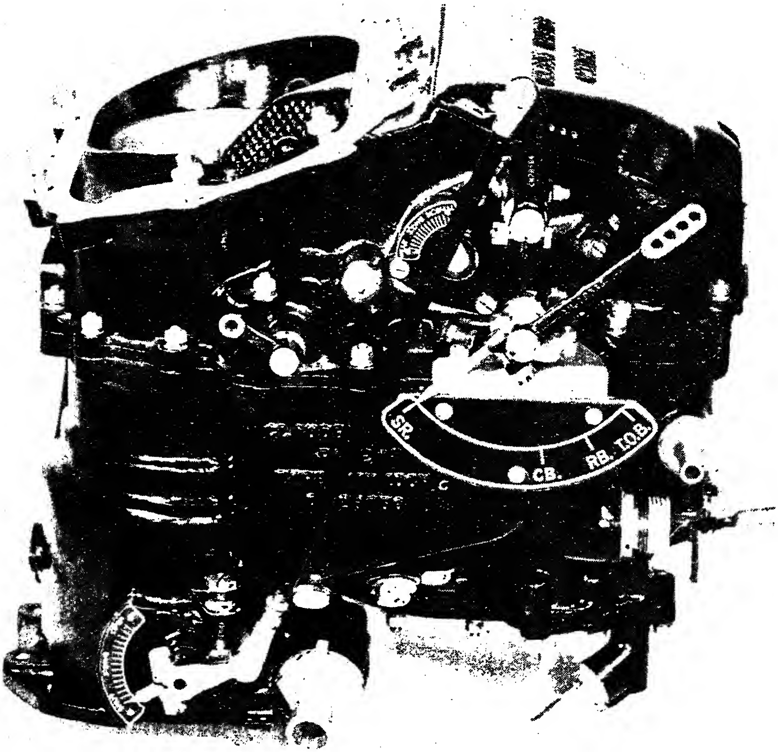


Fig. 28.—Indicator scale and pointer for pilot's throttle-control shaft in a Hobson master-control carburettor

is cruising boost, *B* is rated boost and *C* is take-off boost. Note the different positions of the servo piston and compressions of the capsule.

A small range of boost adjustment is given by the cruising boost and take-off tappets, approximately $\frac{1}{4}$ lb. either way. Outside this figure interference takes place between individual cams, so that the lift of the cams has to be designed to suit the desired three ranges of boost pressure.

When adjusting a three-phase boost control, it is important that the adjustments are made in the following sequence (referring to Fig. 26) :

Open the pilot's throttle lever on the carburettor until the pointer is at the rated boost position and turn the adjusting screw *A* over the capsule until the correct rated boost figure is obtained. Fig. 28 shows the indicator plate and pointer on a Hobson Master Control carburettor. The adjustment should then be locked and sealed.

Provided the lift of the cams has been correctly chosen, movement of the pilot's throttle lever to either the take-off boost position or maximum cruising boost position (with weak mixture) should give the correct figures; or within the small range of available adjustment, brought to the correct figures by their respective adjusting screws *D* and *C*. This, of course, assumes that no other trouble exists that would make control of boost pressure difficult to obtain.

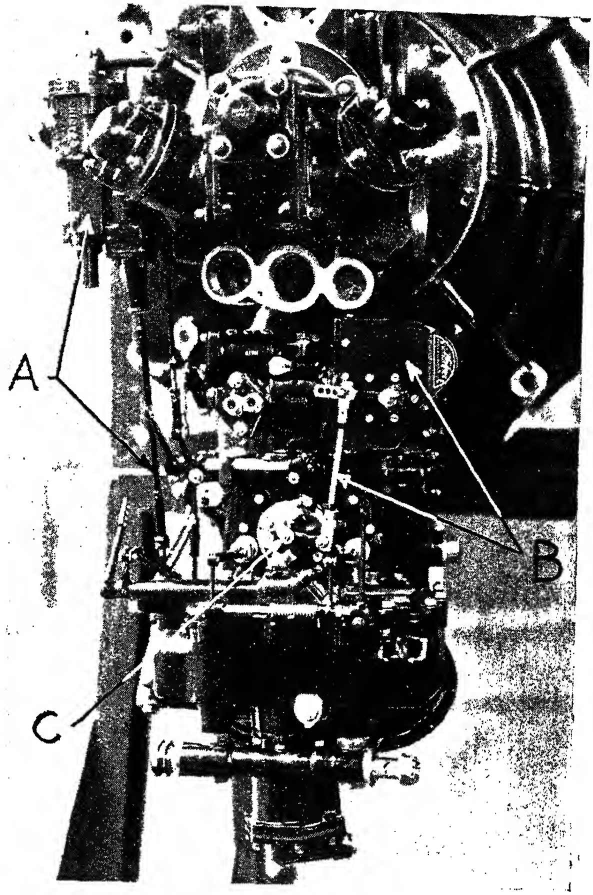


Fig. 29.—REAR END OF AERO ENGINE

Showing boost control and automatic mixture control mounted as separate units. *A* is boost control and its connecting rod; *B* is automatic mixture control and connecting rod; *C* is carburettor altitude valve.

A minimum power stop for the servo piston is also provided in the three-stage boost control. Contrary to the practice of setting it nearly to touch the servo piston at about nine-tenths rated power when using simple boost controls, it is, with a three-stage boost control, set almost to touch the servo piston when it is in the cruising boost position.

Importance of Cruising at Full Throttle with Weak Mixtures

As already explained in connection with Fig. 16, it is desirable under high-altitude conditions to be able to fly with the carburettor throttle wide open but with the pilot's throttle lever in the maximum cruising position, in order that the power jet is not delivering fuel that is unnecessary under conditions of reduced power output. In conjunction

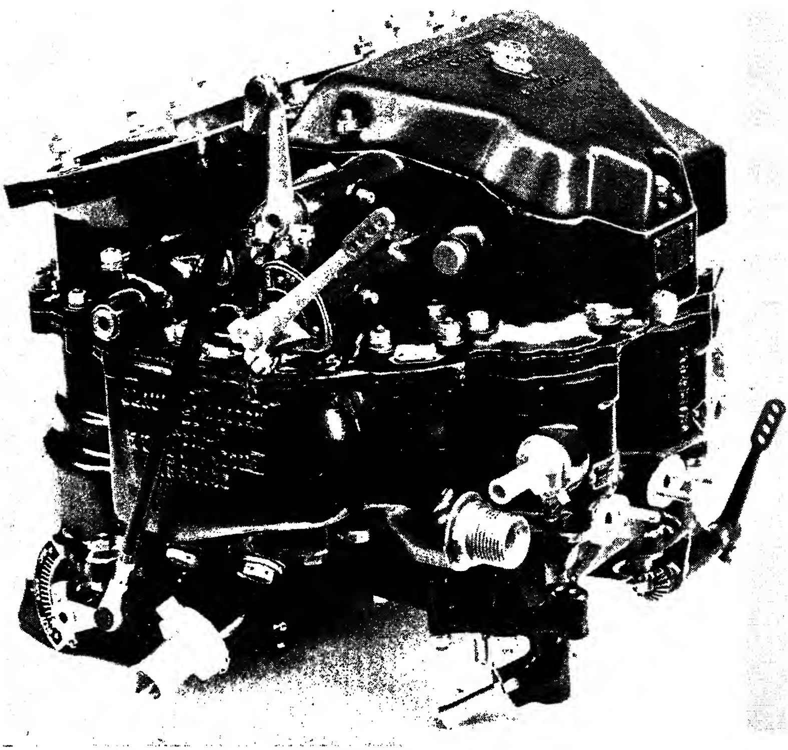


Fig. 30.—Inverted model of Hobson master-control carburettor

with a three-phase boost control, this is obtained by designing the boost control linkage so that in all three located positions, i.e. maximum cruising on weak mixture, rated boost and take-off boost, the carburettor throttle can be either full open or so near to full open that no difference in power output occurs.

Master-control Carburettors

Having perfected the boost control and automatic mixture control, these were in the first instance mounted as separate units at any convenient place on the rear end of the engine. Such an arrangement is shown in Fig. 29 and functions perfectly; but as there was always the chance that some inexperienced person might alter the lengths of the rods connecting these units (and particularly that of the mixture control) to the carburettor, they were built into the carburettor complete with all the necessary linkage and enclosed by an inspection cover. Such a carburettor was given the very appropriate name "Master Control."

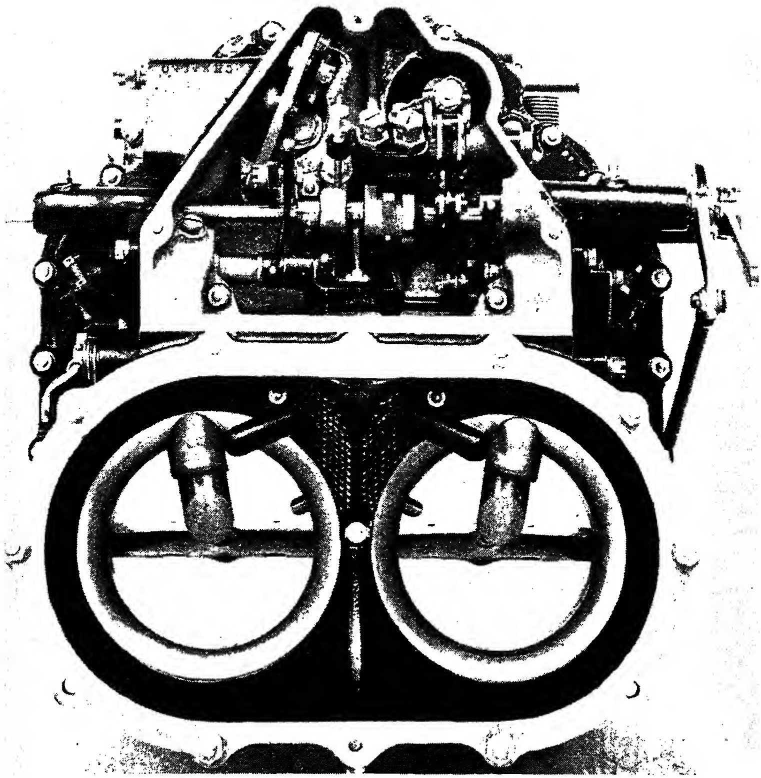


Fig. 31.—Plan view of carburettor showing linkage chamber

Fig. 30 shows a typical carburettor of this type, it being an inverted model. Fig. 31 shows a plan view of the same carburettor with the linkage cover removed.

The boost and mixture control unit can be removed bodily from the carburettor. Fig. 32 shows such a unit stripped to show the various components, the three-stage cam, etc., being part of the upper half of the carburettor. Fig. 32A shows another view.

Pilot's Cockpit Controls

Having reviewed the necessary functions of the carburettor, three-phase boost control and two-stage automatic mixture control, it is desirable to examine the question of the pilot's controls for operating these devices. There must first of all be a lever for controlling the power output of the engine, viz. the throttle lever. The control given by this lever differs as between a non-supercharged engine and a supercharged

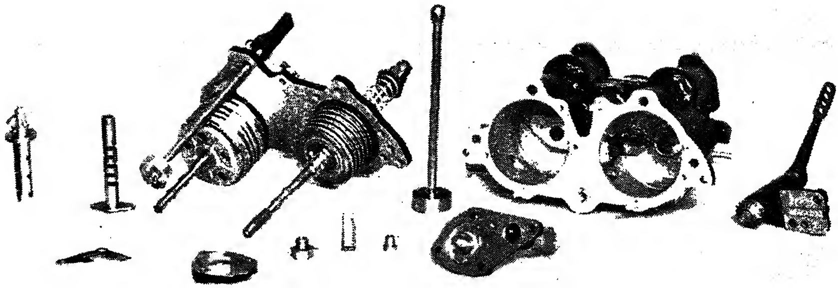


Fig. 32.—Component parts of a combined boost and automatic mixture control

one fitted with a boost control. With the former the pilot has a direct mechanical control of the carburettor throttle opening and thereby the power output ; but with the latter, the effect on the carburettor when the pilot moves his throttle lever is influenced by the boost control up to the engine's rated height.

As regards the control of mixture strength with changes in altitude, with the introduction of the Hobson-Penn Automatic Mixture Control, his mixture lever has now only two settings, one known as " Normal " for maximum power and the other known as " Weak " for maximum fuel economy accompanied by reduced engine revolutions.

In Fig. 33 is shown diagrammatically the pilot's throttle-lever gate for a carburettor fitted with a three-stage boost control. It has three distinct stops corresponding to (1) maximum cruising boost, (2) rated boost and (3) take-off boost and up to rated height the pilot is always sure of obtaining the appropriate preset boost pressure when his throttle lever is placed against any of these three stops. Shown also is the boost-pressure curve obtained with such a control.

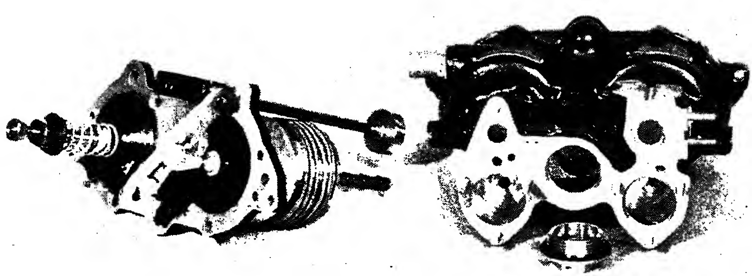


Fig. 32a.—Combined boost and automatic mixture control, showing lower side of casing and top half of unit removed

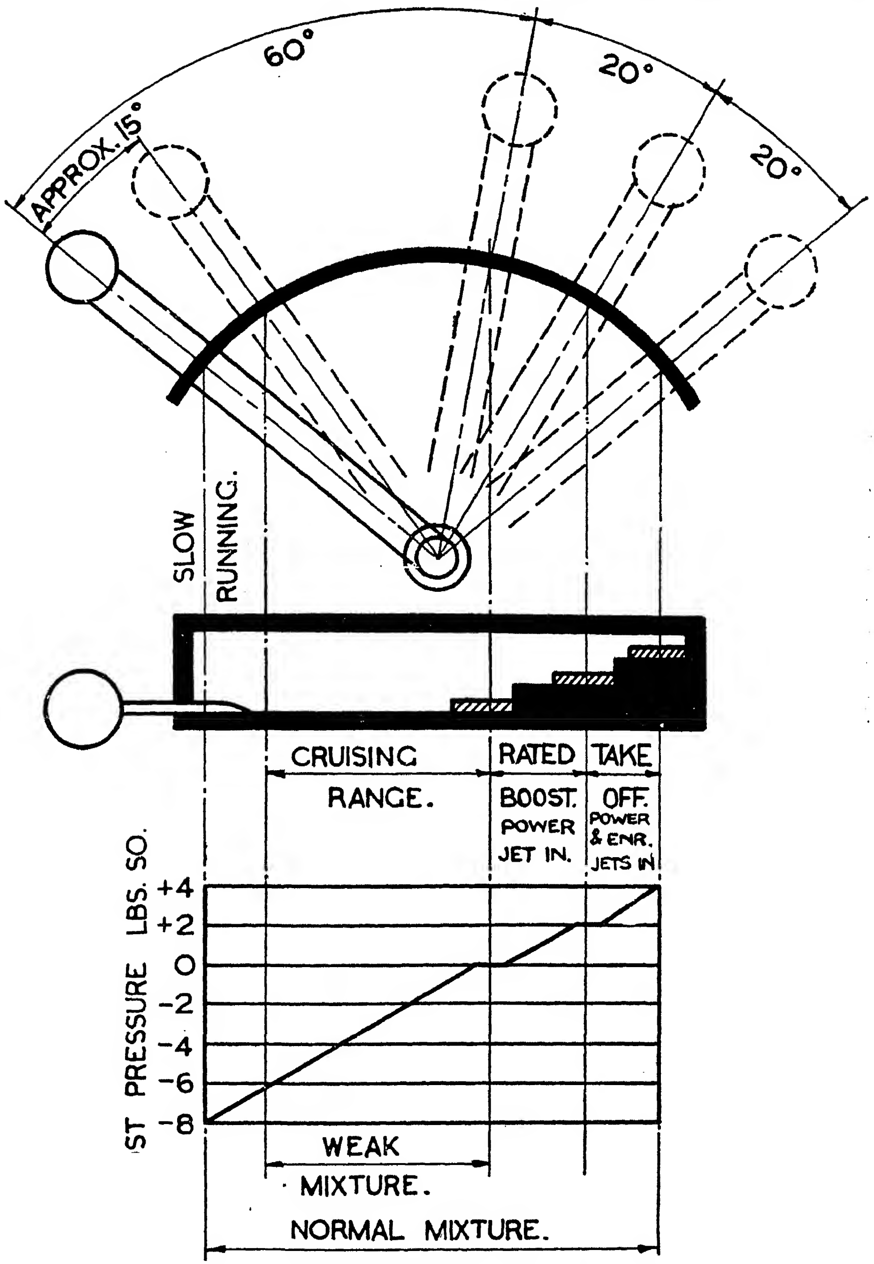


Fig. 33.—Pilot's throttle-lever movement for a three-phase boost control
A boost-pressure curve is also shown, the figures being chosen only as an example.

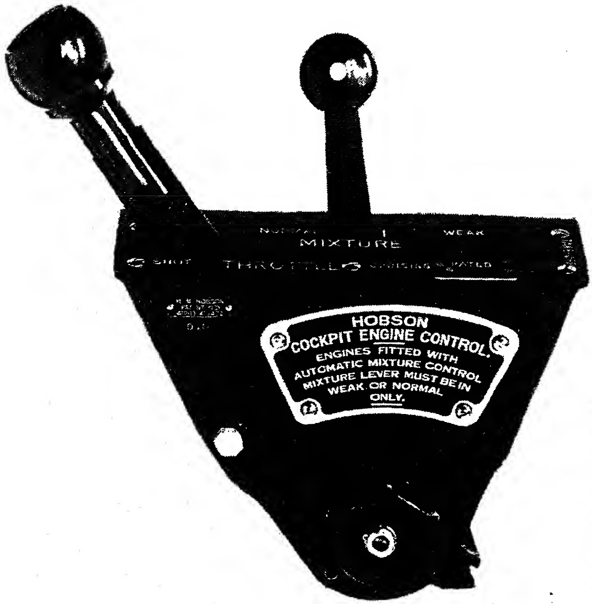


Fig. 34.—A Hobson cockpit control for a dive-bomber, with the pilot's bomb-release switch in the throttle lever

Due to the increased power output, it is strictly necessary for the pilot to remember that as he moves his throttle lever beyond the maximum cruising boost position he must also move his mixture lever to the "Normal" setting and never leave it in the "Weak" setting, or otherwise the engine can be seriously damaged as a result of the high temperatures which always arise. To prevent this happening, a special form of cockpit control known as the Hobson Cockpit Control was put on the market and is made in a variety of designs, each produced expressly for some particular type of aeroplane and its individual engine requirements.

It has long been the practice to arrange that if the pilot closes his throttle with his hand-operated altitude valve left open, the latter is automatically closed to the ground-level position as well. This is necessary in order that the pilot does not inadvertently attempt to land with a mixture too weak to ensure that the engine will not stall, particularly if opened up for a few seconds, as is frequently done while coming in over the boundary of an aerodrome.

The Hobson patent covers a limitation to the movement of the mixture lever, not only when closing the throttle but also when the throttle lever is opened beyond a point giving some specified power output, above which it is unsafe to use a very weak mixture strength. In the Master Control carburettor, this latter point corresponds to "Maximum Cruising." If, therefore, with such a cockpit control, the pilot while cruising with the mixture lever in the "weak automatic" position moves his lever past the "maximum cruising" stop, the interlocking mechanism tries to move the mixture lever back to the "Normal Automatic" setting,

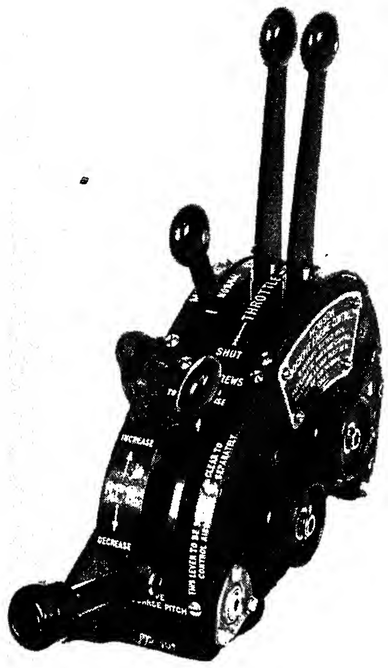


Fig. 35.—A Hobson cockpit control for a twin-engine aeroplane and fitted with a constant-pitch airscrew synchronising device

One mixture lever controls both engines.

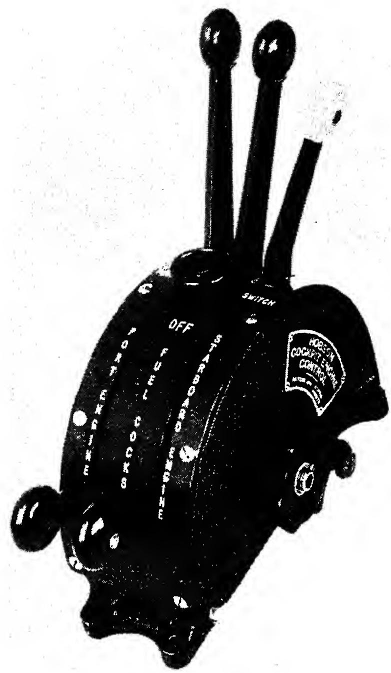


Fig. 36.—A twin-engine cockpit control with machine-gun firing switch (press-button type) and fuel control cocks

the additional load imposed on the throttle lever warning the pilot that he requires a change of mixture strength.

Where the connecting means between the cockpit control and the carburettor is simple and more or less frictionless it is possible for the pilot, by means of his throttle lever, to force the mixture lever from the " Weak Automatic " to the " Normal Automatic " position, but the movement of the mixture lever is primarily the duty of the pilot.

It is possible for the pilot to keep his mixture lever in the " Normal " setting with the throttle lever anywhere between slow running and take-off, so that the pilot can have his throttle lever between the minimum and maximum cruising positions with either a " normal " mixture strength or a weak one ; but when cruising at a safe height he would place the mixture lever in the " Weak " position. For safety's sake, when manœuvring on the ground at small throttle openings, it is undesirable to have very weak mixtures. The pilot should therefore keep the mixture lever in the " Normal " setting until he has finished climbing and then

throttling back to the cruising range, he can change to "Weak Automatic" and thus ensure maximum fuel economy.

From a simple throttle and mixture control these cockpit control boxes have gradually developed into "grouped control" boxes incorporating not only the engine controls but fuel-cock control levers, electrical bomb-release switches, gun-firing switches, synchronising devices for variable-pitch airscrews, landing-light controls, etc. Figs. 34, 35 and 36 show three representative types.

It will be seen, therefore, that the combination of the Master Control (completely automatic) carburettor, in conjunction with the special pilot's cockpit control, ensures absolute safety for the engine in regard to all boost pressures and their appropriate mixture strengths. This is of vital importance, not only to the pilot, who is relieved of all responsibility for the welfare of his engine under every condition of flight, but also to the aeroplane maker, who knows that his published figures for duration of flight are maintained and, in addition, the engine maker has the assurance that his reputation is safeguarded. Yet another factor is a psychological one. In military types, which on active service may change altitude and speed at rapid intervals, the pilot knows that so far as his engine and the range of his aeroplane are concerned, he cannot ruin either through distraction and that he need not observe the multiplicity of instruments that face him if all his attention must be concentrated elsewhere.

THE CAMBRIDGE EXHAUST GAS ANALYSER

THE exhaust gas analyser, when used with a manual-operated mixture control, is a reliable and accurate guide for cruising with maximum economy. When used with an automatic mixture control, it provides a useful check that the best cruising conditions are maintained in flight. With both types of carburettor the instrument gives warning of any trouble relating to incorrect mixture.

The Apparatus

It will be seen from the accompanying diagram (Fig. 1) that the Cambridge apparatus consists of analyser cells placed near the engines, which receive a constant flow of exhaust gas through pipe lines and are welded to the tail pipe of the engine exhaust system. The pipe lines are duplicated, one facing upstream inside the exhaust pipe and one downstream, and the reactions of the analyser cell are communicated by passing the gas through a thermal conductivity cell, where it is electrically analysed by a Wheatstone Bridge, to a recording instrument placed in the pilot's cockpit.

Junction Box

A junction box is placed in the circuit, being located within reach of the pilot by a four-wire cable, and has a sufficient number of terminals so that the analysing cell may be connected easily.

Time-lag

The time-lag of the instrument is in direct proportion to the flow over the analyser cells, and when cruising the lag is not more than 15 seconds. The instrument will not read until the mixture control is set to give an air-fuel ratio of less than 0·090, or before the needle will move off the " Full Rich " mechanical stop.

The manual mixture control is frequently more sensitive than a pilot who is accustomed to setting r.p.m. would ever believe, and difficulty may be experienced in getting the needle to stop at the desired spot. It should be remembered that the strength of the mixture passing to the engine is influenced by a number of factors other than the mere operation of the mixture control lever, such as changes in altitude and air temperature. With some carburettor systems also, throttle position,

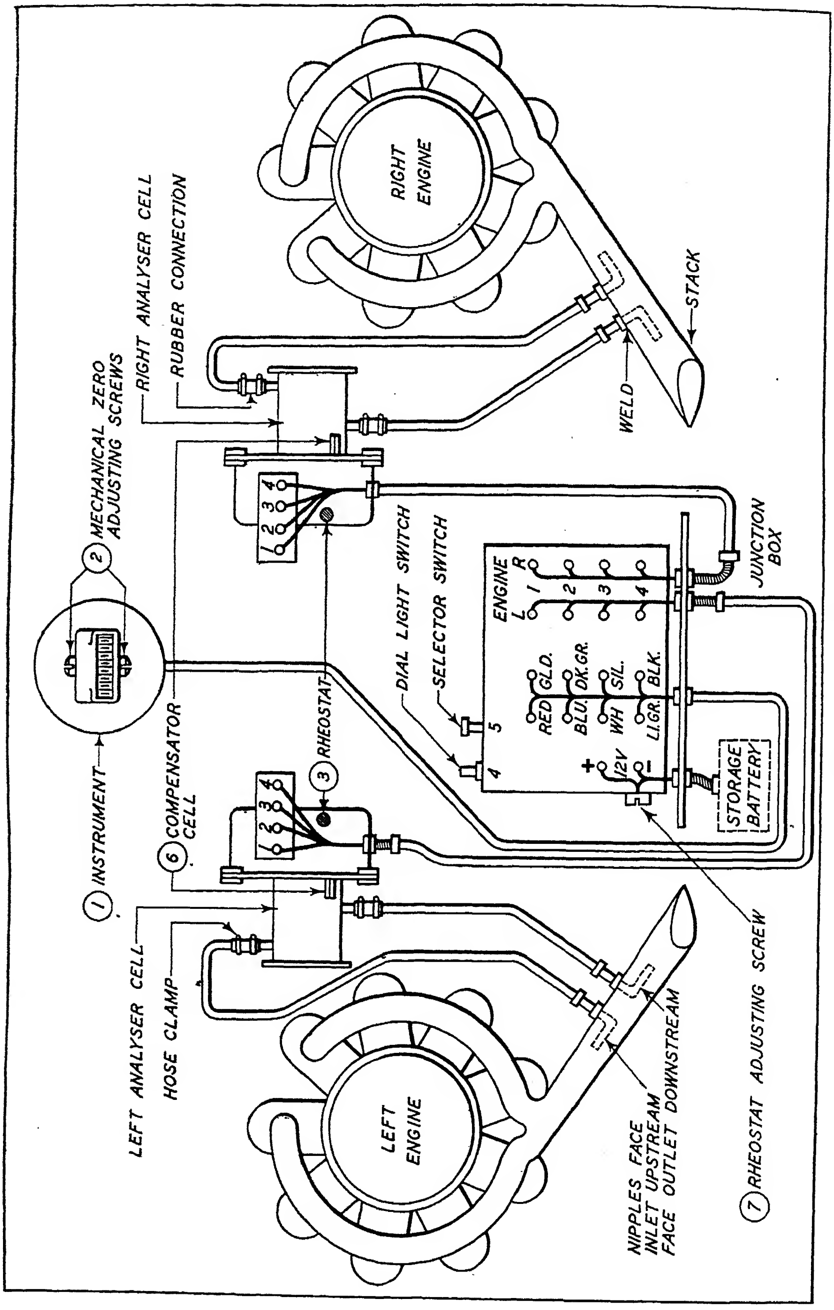


Fig. 1.—CAMBRIDGE EXHAUST GAS TESTER

indicated air speed, fuel-pump pressures, the attitude of the aeroplane, etc., will affect the ease with which the needle can be maintained in a stabilised position. When carburettor heat is applied, the mixture indication on the dial goes rich, and it will be necessary to readjust the mixture after the heat has been applied; also, when the heat is turned off, the needle will show weak until possible detonation is started, so before shutting off the heat always richen the mixture first.

Operation and Maintenance

There are three important adjustments necessary for the correct operation. Firstly, the instrument zero adjustment; secondly, the current adjustment, and thirdly, the electrical zero. They should be made as follows:

(1) Instrument Zero Adjustment

The mechanical zero on the instrument is made with the selector switch on the junction box in the "off" position; the upper and lower pointers of the instrument should stand at the line marked A on the scale of the dial. If they do not, adjust the screw on the top of the instrument for the top needle and the lower screw for the lower dial.

(2) Current Adjustment

The current adjustment is made with the selector switch in the "STD" or standard position. The top needle should move to the extreme left of the dial and stand at the point marked B; if it does not, adjust the rheostat on the side of the junction box until it does. A screwdriver can be used to move the rheostat while the current adjustment is being made.

The upper pointer on the instrument will respond to this adjustment, but the lower one will not. There are two switches on the junction box, one of which is marked "Off–On" (the instrument dial light) and the other is the selector switch marked "STD Off–On."

(3) Electrical Zero

To adjust the electrical zero, remove the filter cover and bronze filtering wool from the analyser cells, then place inside this filter compartment a clean rag or waste moistened with water and wrung out, after which replace the cover. Allow the instrument to stand for half an hour and then turn the selector switch to the "on" position, whereupon the needles should take up a position on the A line. If they fail to do so, further adjustments should be made by altering the rheostat inside the analyser cell. After adjustments have been made, the filter wool and cover should be replaced. The bronze filter wool collects oil and particles of carbon.

Testing for Pivot Friction

Ground checks are considered unsatisfactory, because the rates of flow of the sample through the analyser cells are too low, and low throttle settings do not reproduce normal cruising conditions. To test the instrument for pivot friction, make sure the needle moves to the B position when standardising, and if it moves back smoothly to the A position, this indicates no pivot friction. If it stops short and moves to the final position after tapping pivot, friction exists, and the instrument should be returned to the makers.

If in some instances the fuel supply is low, the instrument will show the drop in the mixture strength, before the fuel-pressure gauge will have appreciably moved and provided a reliable check. If the needle stays in the centre of the dial near the A position, it is probable that the pipe-line is broken or else the instrument switch is off, but if on the other hand the needle creeps towards full rich or fluctuates under normal operating condition with constant-mixture control and throttle settings, it is a definite indication of detonation. The mixture should be richened and then weakened to a position where it does not fluctuate. This position will be a slightly richer setting than before the disturbance.

Thus, if the needle moves towards rich position, the mixture should be richened until the needle moves towards "weak," and this is the main function of the apparatus. If, however, the instrument does not respond to operation of the mixture-control lever, it would indicate either an error in the wiring or else the nipple in the exhaust pipe is situated wrongly or blocked with ice or dirt. It might also indicate back-pressure on the analyser cell outlet.

Needle Deflects Violently

The only other fault that is likely to occur is if the needle deflects violently from one side to the other at a normal throttle setting and mixture-control lever correctly set or when the instrument is switched on to the analyser cell with no exhaust flowing. This symptom would appear to indicate again that the wiring has broken down. If this is not the case, the analyser cell should be exchanged for another, and if the electrical zero can be adjusted satisfactorily, the trouble lies in the first cell. If it cannot, the trouble should be looked for at either the junction box or the instrument itself. These can be exchanged in the same way, as the units are interchangeable, and the fault is thus easily located.

STROMBERG AIRCRAFT CARBURATION

IN a previous article dealing with the servicing of the Stromberg NA—S2 and NA—S3 carburettors for small engines, brief reference has been made to the general principles of these carburettors. Before dealing in detail with the servicing and maintenance of other types of Stromberg carburettors, the engineer should have some knowledge of the fundamental principles on which they are based. These principles can in fact be applied to most makes of carburettors.

Simplest Form of Carburettor

Fig. 1 shows the very simplest form of carburettor. It comprises the bare necessities of float chamber (A), choke tube (C), and one jet (B).

This provides a reservoir and an outlet for the petrol. The first problem is to extract the petrol from the reservoir (or float chamber).

The obvious means of extracting petrol from the float chamber through the jet is to force it out by piston pressure, as shown in Fig. 2. Although it is not possible to do so mechanically, the same effect is obtained by another means. As the carburettor is bolted on to the induction manifold, the choke area is in direct communication with the engine cylinders (Fig. 3). When a piston falls on its induction stroke, a suction is created in the engine manifold and in the carburettor choke area, with the result that there will be a pressure drop at the head of the jet.

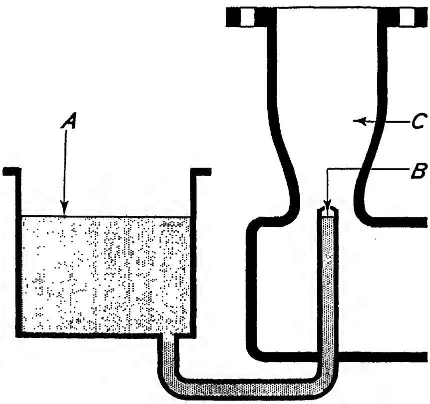


Fig. 1.—A SIMPLE CARBURETTOR
A, reservoir; B, jet; C, choke area.

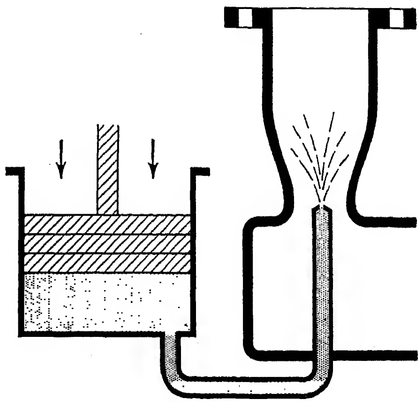


Fig. 2.—PISTON EFFECT OF VARIATION IN PRESSURE BETWEEN RESERVOIR AND JET OUTLET

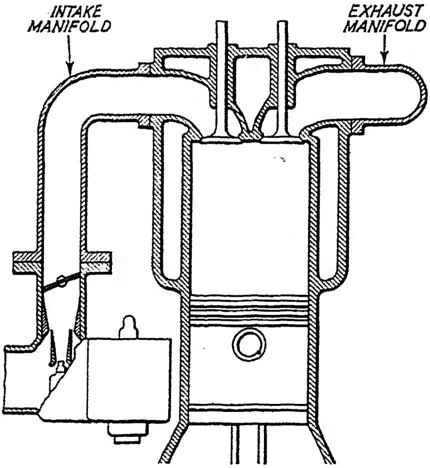


Fig. 3.—CARBURETTOR COMMUNICATION TO CYLINDER OF ENGINE BY MEANS OF INDUCTION PIPE

There will be no change in the pressure being exerted upon the petrol in the float chamber, however, as this part is open to atmosphere. Pressure therefore will be maintained at 14·7 lb. per square inch, whilst sea-level conditions are maintained. Consequently the desired piston effect is obtained and petrol will be forced out of the jet.

Varying Speeds and Loads

The simple carburettor just described might, with careful selection of choke area and jet sizes, suffice to operate a constant-speed engine with fixed load. Engine speeds and loads, however, vary over a very wide range, from slow running with no load on the engine to flat-out engine speed with full load. Each intermediate condition calls for a certain mixture of petrol and air, and a varying volume of that mixture. It is the duty of the carburettor to cope with all these requirements.

Throttle Plate

The first requirement is to incorporate some arrangement to control the volume of the mixture. This is done by including a throttle plate, as shown in Fig. 4. The throttle plate is a "damper" placed across the bore of the carburettor on the engine side of the jet outlet. The plate rotates on a spindle, and consequently can be turned to open fully, and in this position creates the minimum restriction. The more the throttle is closed the greater is the obstruction placed across the inlet passage.

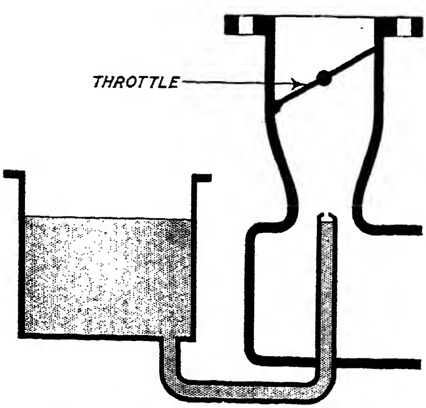


Fig. 4.—PLAIN CARBURETTOR WITH THROTTLE INCORPORATED

It has already been shown that with no throttle, as in Fig. 1, the cylinder of the engine is enabled to fill itself with mixture upon its induction stroke. It now

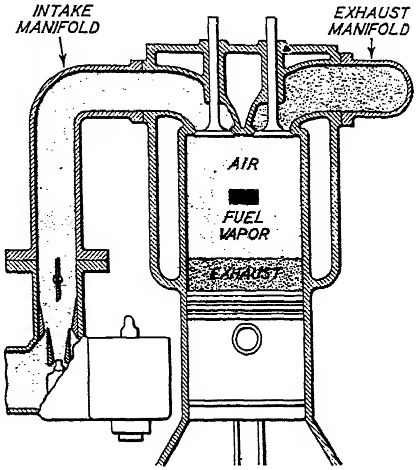


Fig. 5A.—Fuel/Air proportion

follows that the greater the obstruction caused by the throttle plate, the less "filling" will be possible to the cylinders on their induction strokes. This causes a less powerful explosion or power impulse to be created, and thus the speed/power output of the engine is controlled.

Petrol/Air Mixture

The above principles can now be followed with more detail in conjunction with each other. In the first place it is necessary to know the proportion of petrol to air that is necessary to form a combustible mixture. Petrol will burn in a cylinder if mixed with about eight to sixteen times its weight of air, i.e. 0·125 to 0·062 lb. of fuel to each 1 lb. of air. Overlooking the question of consumption for the moment, and dealing with maximum power only, this is obtained from a mixture of 12 to 14 parts of air to 1 part of petrol (0·083–0·071 lb. fuel to 1 lb. of air). Some idea of the effect value of mixture can have upon the power output of an engine can be gained from the full throttle power curve shown in Fig. 5B. It will be seen that both weak and rich mixtures can cause considerable power loss. The curve shown naturally does not apply to all engines,

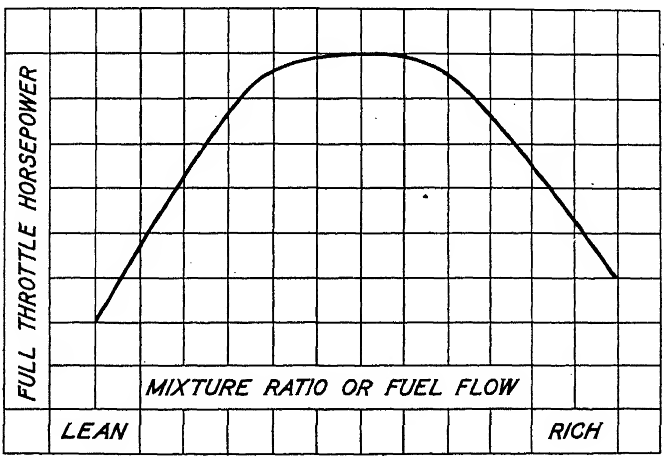


Fig. 5B.—Full throttle power curve

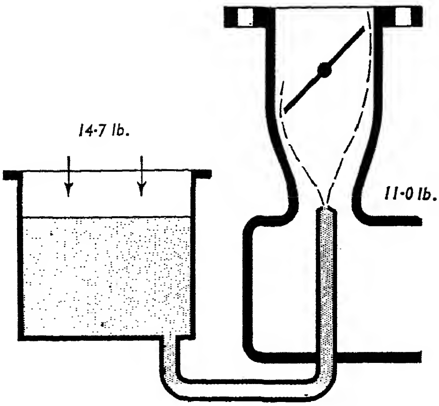


Fig. 6.—PRESSURE VARIATION AT IDLING SPEED

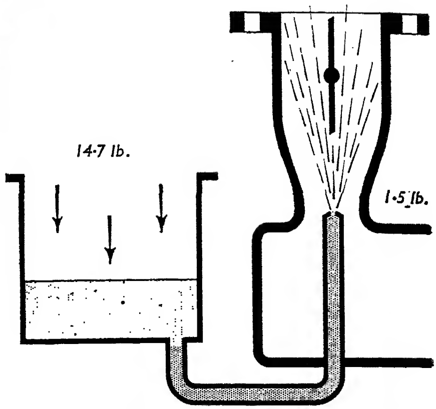


Fig. 7.—PRESSURE VARIATION AT FULL THROTTLE

The jet outlet is theoretical only.

as many varying characteristics of engine design cause different effects, but it can be accepted as being typical. Fig. 5A shows relative proportions of air, fuel vapour, and residual exhaust gas at beginning of compression stroke (full power).

Constant Load

The next thing is to follow the functioning of the simple carburettor at different engine speeds, but with constant load. Imagine the engine running at its lowest speed—that is, idling. The throttle is practically closed, as shown in Fig. 6 ; consequently, the suction (or depression drop) caused by the engine piston movement is obstructed by the throttle plate, and is only partly felt in the choke area. Actually, the pressure here when idling will be 9 lb. to $11\frac{1}{2}$ lb., but the float chamber is open to atmosphere, and consequently pressure is maintained at 14·7 lb. per square inch. This variation in pressure will cause petrol to be forced out of the jet. This will be taken up by the air rushing past the throttle to fill the partial vacuum caused by the moving engine pistons. By this method the air and petrol are mixed at a proportion to ensure good burning once it is ignited in the cylinders.

To increase the engine speed, the carburettor throttle is opened wider. The effect of this is to allow greater suction to be present in the choke area of the carburettor and to permit an increased volume of air to be drawn through. As the effect of the depression drop in the choke area is to increase the petrol output, the result will be a greater volume of petrol/air mixture which creates more power upon being " fired " and causes the engine speed to increase.

Full Throttle Position

At the full throttle position (Fig. 7) there is very little restriction caused by the throttle plate and spindle, and the maximum amount of air is

being drawn in by the cylinders. It follows that extra petrol must be supplied, and this is assured, because depression or suction in the choke area is now only about 1·5 to 3·0 lb. per square inch below atmospheric pressure, which still remains constant in the float chamber. The result is that an increased quantity of petrol is forced out of the jet to mix with the greater volume of air passing into the engine.

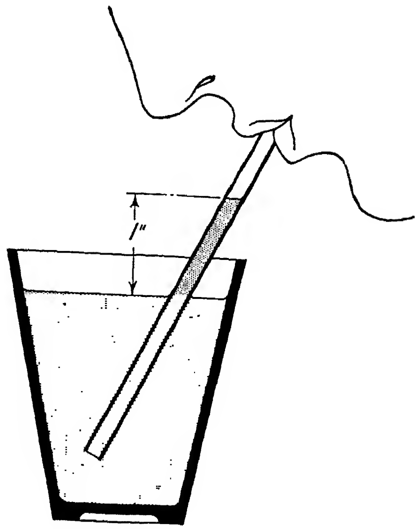


Fig. 8.—Showing how suction may lift a liquid without drawing any of it away

Law of Liquid Flow

Now, if the simple carburettor with which we have been dealing was set when idling to give the correct fuel ratio, then this ideal mixture would be maintained throughout the throttle range, *provided the flow of air and petrol were to increase in the same proportions*. This, however, is not the case. There is a "Law of Liquid Flow" to be considered which is "that the flow of liquids increases under suction faster than the flow of air."

Under increasing suction, the simple carburettor described will provide a richer mixture. This is particularly so during medium and high engine speeds. During the period of low engine revolutions, the jet delivery will fall off in relation to the air flow.

This can be attributed to the fact that some of the suction force is consumed in raising the fuel level to the jet outlet. Obviously, the normal level of petrol must stand at some distance below the jet outlet, to prevent overflow when the engine is not running. Additionally there must be some tendency for the petrol to "cling" to the outlet of the jet, and some suction is dissipated in overcoming this. This reduction in flow is perceptible when suction is low, but may be considered insignificant when high.

Mixture Compensation System

It is therefore necessary to devise an arrangement that will overcome the "richer-mixture-at-greater-suction" and "low-speed-jet-delivery-loss" difficulties. A mixture compensation system must be introduced. On the Stromberg, it is achieved by air bleeding the simple jet which has

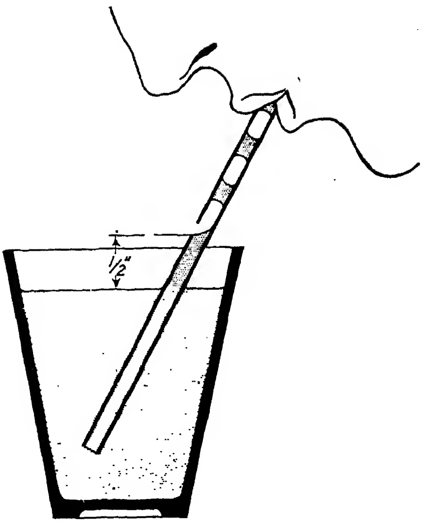


Fig. 9.—SHOWING HOW SUCTION IN FIG. 8 MAY BE MADE TO DRAW LIQUID BY THE ACTION OF AN "AIR BLEED"

A small hole has been pricked into the side of the straw above the level of the fuel.

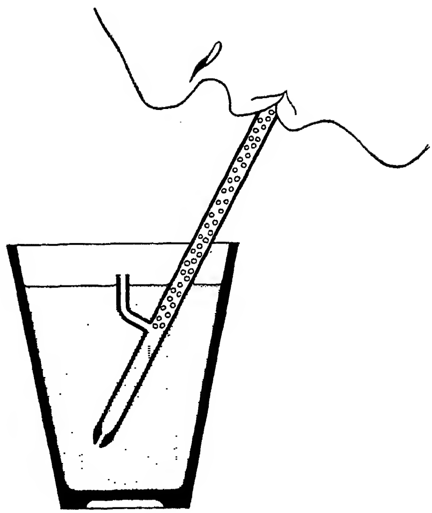


Fig. 10.—SHOWING A MORE EFFECTIVE APPLICATION OF THE "AIR BLEED" PRINCIPLE

Giving a finely divided emulsion and reducing the retarding effect of lifting the liquid above its level.

been described above. It can be described by a few simple illustrations. Fig. 8 shows the simple jet operation. Imagine the open glass is the float chamber filled with liquid to a predetermined level. A straw is inserted to represent the jet. Suction is placed on the straw to draw the fuel out of the glass (compare this simile with the simple carburettor, Figs. 6 and 7). The heavier the suction, the greater will be the amount of fuel extracted. This follows the "Law of Liquid Flow" system previously detailed, and explains simply the increasingly rich mixture that follows as suction increases with higher engine revolution.

The theory of suction loss at low engine speeds, due to the necessity of raising the fuel level first, in order to extract petrol, is also plainly illustrated. In Fig. 8 it will be seen that suction has been expended to lift liquid up the straw without drawing any of the fuel away.

Next look at Fig. 9. The only change made is to prick a small hole into the side of the straw above the level of the fuel. If the same suction is applied to the straw as was used for the Fig. 8 demonstration, fuel will then rise higher up the straw and be drawn away, because air is entering the small hole and liquid is being carried up the straw in a series of small drops.

It will be seen, however, that there is still some distance for the liquid

to be lifted from its level before the air begins to pick it up. Furthermore, the "free" opening of the straw at its base prevents very great suction being exerted on the air bleed hole. Alternatively, if a larger air hole was used, the suction available to lift the fuel would be reduced. These difficulties led to modifications being embodied, as we can see in Fig. 10. By the arrangements shown, air is taken to a point in the straw below the fuel level and a restricting orifice is placed at the base of the straw. In this simple manner both the objections to the system shown in Fig. 9 are overcome.

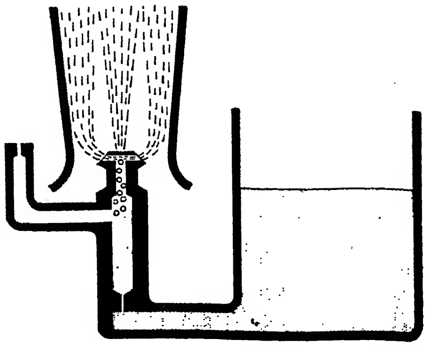


Fig. 11.—A CARBURETTOR NOZZLE EMPLOYING THE "AIR BLEED" PRINCIPLE; THE STROMBERG MAIN DISCHARGE JET

Practical Necessities of Carburettor Manufacture

Now to apply the diagrammatic principles of Fig. 10 to the practical necessities of carburettor manufacture. Fig. 11 shows the results. This, in fact, is the Stromberg main discharge jet. This jet is located in the centre of a definitely formed air intake or choke tube, both jet and choke tube being positioned on the atmospheric side of the throttle plate.

Another natural law must now be considered, but this time it acts favourably on behalf of the Stromberg air-bleed jet principles. It is to the effect that "both the air flow through a jet of fixed size (the choke tube) and the fuel flow through an 'air-bleed' jet system, respond in substantially equal proportion to changes of suction."

Under this law, then, it is only necessary for the air-bleed main-discharge jet and the choke tube to be subjected to engine suction to the same degree in order to maintain a mixture approximately uniform in proportion throughout the power and speed range of the engine. This is made possible by placing the jet outlet in the centre of the narrowest part of the choke tube. Fig. 11 shows this clearly. Both jet and choke tube are then positioned on the atmospheric side of the throttle plate.

As the throttle plate opens wider, the engine speed increases because of the higher depression (or suction) transferred to the atmospheric side of the throttle. This, as we have now seen, increases the fuel output of the jet in proportion to the increased volume of air drawn through the choke tube.

Choke Tube

When the throttle is wide open and maximum engine speed is attained, the utmost volume of air possible is passing through the choke tube.

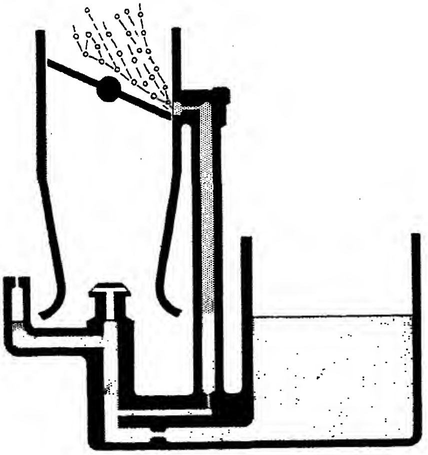


Fig. 12.—The Stromberg idling system

Showing combination of an idling passage beyond the throttle. Note the location of the restrictions in the idling channel.

It is for this reason that various choke-tube sizes are used, according to the requirements of the engine. The objective of the carburettor tuner is to use the smallest choke tube that will pass the required maximum volume of mixture. By so doing he ensures that the speed or velocity of the mixture through the carburettor is maintained as high as possible (always an important factor with which to contend). It is usually found that the correct choke tube passes the necessary volume at a velocity of 300 ft. per second through the narrowest part of the choke tube, when the engine is at normal full speed and load during the induction stroke.

This completes the general basis of carburation. At one time that was all there was to it ; but the demands upon the carburettor are ever increasing. Greater power, more rapid acceleration, and greater fuel economy are some of the requirements of the engine makers, as well as the natural refinements that follow to enable the carburettor to operate at all under aero conditions.

The Modern Aero Carburettor

The modern aero carburettor can be divided into these phases or circuits :

(1) The idling system.
(2) The accelerating system.
(3) The economiser system.
(4) The main metering system.
(5) The altitude mixture control.
(6) The fuel level control.

(1) The Idling System

When the engine is idling, the throttle plate is practically closed. Under these conditions the suction on the engine side of the throttle must be very high, but the pressure on the atmospheric side is practically nil. It is because of this that in actual practice Fig. 6 does not apply. In fact, there is insufficient suction at the main jet outlet to cause petrol to be drawn from this part. But it remains necessary to provide the fuel for the engine so that it may " tick-over " at the desired speed.

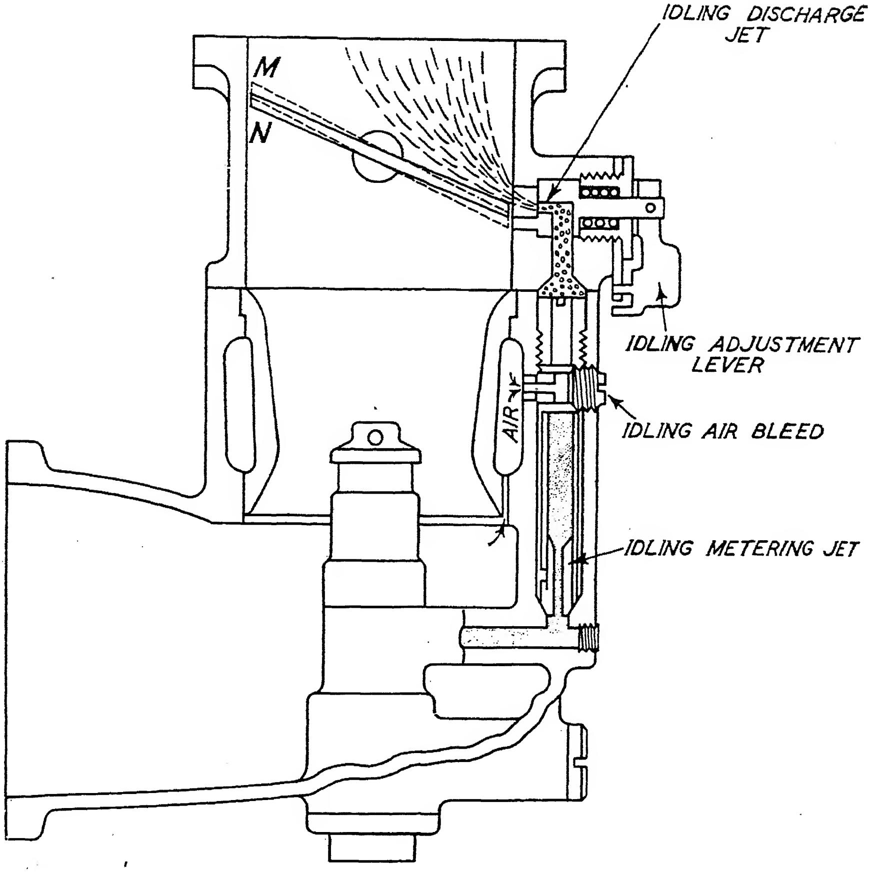


Fig. 13.—TYPICAL IDLING METERING SYSTEM

Petrol must be drawn from the float chamber somehow in order to achieve this. As the suction is on the engine side of the throttle, then this must be brought into action somehow. Fig. 12 shows how this is realised.

A drilling is made to break into the bore of the carburettor just on the engine side of the throttle plate. This drilling is connected to another that runs down the bore of the carburettor to the petrol that is supplied from the float chamber. It will now be clear that when the engine is rotated and the suction is created on the engine side of the throttle, petrol will issue from the drilling to provide fuel for idling speeds. The petrol-air ratio of this fuel must be carefully measured, and a jet with air

bleeding must be placed in the circuit for this purpose. In fact, the idling circuit may be considered as a miniature discharge jet system of its own, working almost independently from the main carburettor.

Actually the metering of the fuel for idling purposes is often no easy proposition and leads to carefully designed idling systems being incorporated in the carburettors.

Fig. 13 illustrates but one of the variations of the basic principles that are likely to be encountered. Let us give it a closer examination, and see the adaptations that have been made to provide the best results. First there is a variation to the idling outlet to the engine side of the throttle plate. The reason for this is that when the throttle is closed the suction above it is at its greatest. But at this stage the engine is at its lowest speed, when the least air and consequently the least petrol is needed; yet when it is necessary to increase speed and more fuel is needed, the suction on the engine side of the throttle diminishes. Steps must be taken to overcome this difficulty.

A small slot is formed by the idle discharge nozzle (seen in Fig. 13) and the bore of the carburettor, so that when the throttle is closed the slot has openings into the bore of the carburettor both above and below the throttle edge.

When the throttle is in position N, that part of the idling slot exposed to the atmospheric side of the throttle is considerably greater than that exposed to the engine side. We know that suction on the large part is very low, whilst that on the small part of the exposed slot is heavy. The result will be that the mean suction of the two parts now being concentrated upon the idle discharge-jet orifice is more nearly the low suction that is present on the "atmospheric" side of the throttle plate than that on the engine side.

At this stage a satisfactory mixture is produced to cause the engine to turn at about 400 r.p.m. (airscrew load). Now, to increase the speed to, say, 600 r.p.m. with the same load, it is necessary to open the throttle to a position approximating to that shown at M in Fig. 13. This provides an increase of about 50 per cent. to the air supply, and an increase to the petrol output is also necessary to ensure the necessary mixture ratio. A greater suction on the idle discharge is wanted for this. It is provided by the design and disposition of the idle slot.

With the throttle plate in position M, less of the slot will now be exposed to the "atmospheric" side of the throttle, but a greater part of the slot will now come under the heavy suction on the engine side of the throttle. Consequently suction on the idle discharge jet will be greater than was the case when the throttle was in the 400 r.p.m. position N shown in Fig. 13.

When a greater speed still, say 900 r.p.m., is needed, the throttle is, of course, opened wider. This causes a greater inlet for air, and also causes all of the idle slot to be exposed to the heavier depression on the

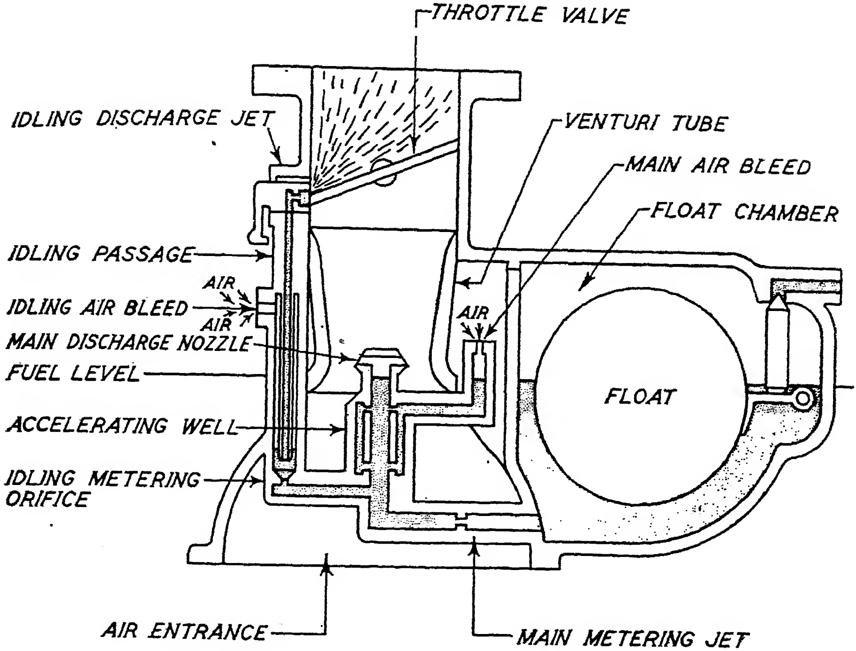


Fig. 14.—CONDITION OF IDLING SYSTEM FOR STARTING

Note that idling passage draws unrestricted fuel flow (without " air bleed ") from space around idling tube, thus giving temporarily rich mixture and automatic priming action. When this space is emptied and engine starts, the idling "air bleed" begins to operate as in Fig. 15.

engine side of the throttle. The fact of exposing the *whole* of the idle slot to the suction on the engine side of the throttle causes greater suction to be exerted upon the idle discharge jet, although we know that the source of the suction or depression is less than was being exerted previously on *part* of the idle slot.

Now study the remaining " build-ups " from the simple idle system shown in Fig. 12. The idling system has been described as a miniature discharge-jet scheme of its own. To justify this description, a jet with air bleeding must have been added to Fig. 12. It can be seen in Fig. 13. The jet is placed at the bottom of the long drilling and the air bleeding is provided some distance higher up. Remember, the positions of these parts may vary on different idling systems, but they are there just the same, and their disposition must not be misleading.

Follow now how the typical idling system of Fig. 13 goes into action. Figs. 14 and 15 show the detail. With the throttle closed to position N the engine is rotated. This causes suction to be felt upon the idle discharge jet, and petrol is at once drawn from the idling passage. This passage leads to an idle well, at the head of which is placed the idling

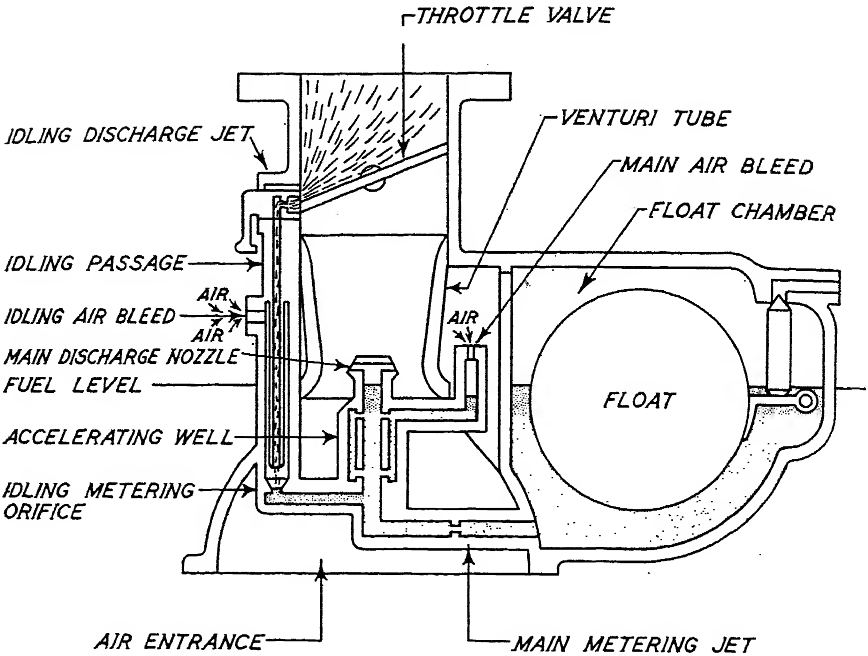


Fig. 15.—Conditions while engine is idling.

Fuel flow of normal mixture strength taken through restriction of idling metering orifice, joined by air of idling "air bleed" and fed in fan-shaped spray across mouth of carburettor above throttle. Note accelerating well nearly full.

air bleed. At first, petrol only will be drawn from the idle well and passage to be discharged from the jet into the induction manifold and engine. This rich mixture is intended as an automatic primer for starting the engine.

Once the engine has started, however, the idle well will have emptied and the base of the idling passage will be open to the idling air bleed. The similarity of the idling system to the main discharge jet system can now be seen.

The idling metering jet (or orifice) is now subject to atmospheric influence and mixture compensation is thereby assured.

The engine will now continue to idle by means of the mixture issuing from the idle discharge jet.

Adjustments for Idling

From the foregoing descriptions it will be realised that the features controlling the idling output are :

(1) The position of the throttle in relation to the idle slot.
(2) Size of the idle metering jet.
(3) Size of the idle air bleed.

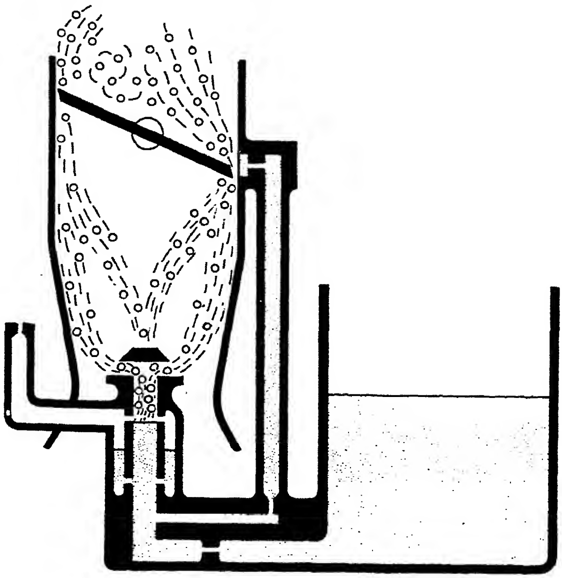


Fig. 16.—Accelerating well with main discharge jet and idling passage

Features 2 and 3 can be said to affect the idle output about equally during the entire idling range, from the lowest speed up to, say, 1,000 r.p.m. The best size for these parts is decided upon after exhaustive tests have been made with all combinations for the engine on which the carburettor is to operate. Consequently they are made of a fixed size, and adjustment for idling is left to varying features. This is possible by rotating the idle discharge nozzle by means of a lever on the outside of the carburettor. This lever works against a quadrant to indicate the range of adjustment. The idling discharge nozzle is rotated by this means to expose more or less of the idle slot area to the engine side of the throttle according to requirements. The greater the area exposed, the heavier will be the suction on the discharge jet, and a richer idling mixture will result. The range of such adjustment is confined particularly to the very low speeds and is ineffective beyond 600–700 r.p.m.

The idle air bleed provides a very effective adjustment to speeds between 700 and 900 r.p.m. without affecting the very low- (or high-) speed idle. A larger air bleed will cause depression or suction drop on the idle metering jet and a weaker output will result. If a richer mixture is required, it can be obtained by providing a smaller idle air bleed.

The illustrations used for this detailing of the idling circuit show the metering jet or orifice located at the bottom end of the idle passage. This is the usual practice; but do not be misled if it is found positioned elsewhere in the idling system. If it is a separate jet screwed into position, make quite certain that it seats securely. Should it fail to do so, the effect of a larger metering jet will be obtained. This will result in a richer mixture at low engine speeds and a weaker mixture at full throttle owing to larger reverse air bleed into the main jet system.

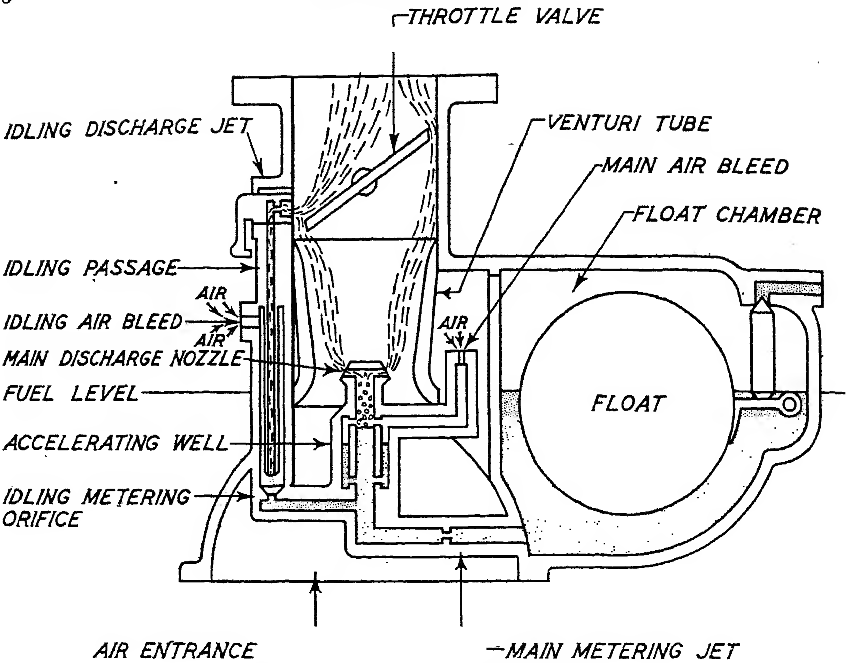


Fig. 17.—Throttle partly open

Giving about 900 r.p.m. The main discharge jet and idling discharge jet are both in operation. The accelerating well is partly emptied.

The Accelerating System

When the throttle is opened off the idling position in order to accelerate or increase the engine speed, depression on the engine side will fall, but suction on the atmospheric side will increase. The increase will be felt particularly at the outlet of the main discharge jet owing to its position in the narrowest part of the choke tube. The depression in the float chamber is still maintained at atmospheric pressure, however, and consequently petrol will flow from the jet and is carried by the inrushing air-stream into the manifold and engine.

Now it can well be imagined that sudden transfer of depression from the idling outlet to the main discharge-jet well calling for rapid acceleration is likely to create a "pause" in the progressive increase of fuel supply owing to a temporary lack of fuel.

To overcome this an extra supply of fuel must be made available for acceleration purposes. There are many methods of providing this, but they can be generalised under two headings: (*a*) the accelerating well system; (*b*) the accelerating pump system.

(*a*) The Accelerating Well System

Fig. 16 clearly illustrates this system. The "well" may be described as a downward enlargement of the air bleed passage to form a pocket

around the main discharge jet drilling. Drillings are then made so that petrol can pass from the jet drilling to fill the pocket around, up to the common level.

We know that the pocket is open to constant atmospheric pressure, and as a result the central channel of the jet drilling will always be under greater suction or depression when the throttle is opened with the engine running.

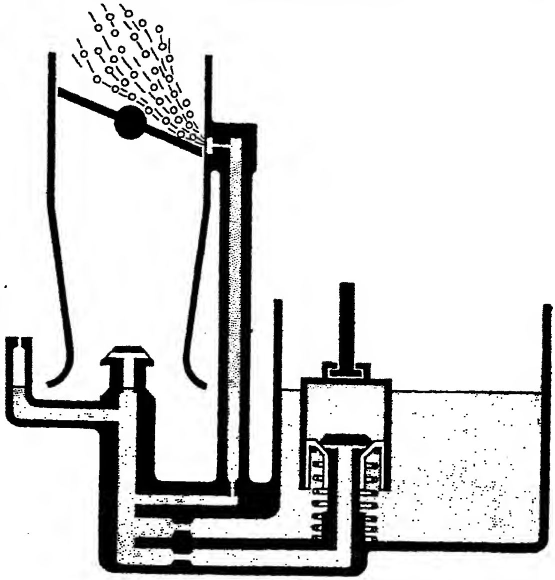


Fig. 18.—ACCELERATING PUMP OPERATED BY THROTTLE WITH MAIN DISCHARGE JET AND IDLING PASSAGE

It follows then that when the throttle is opened for acceleration purposes and fuel is drawn from the main discharge jet, it will be replaced immediately from the supply in the pocket or well. This ready replacement overcomes any trouble that may otherwise have been caused by the natural lag that will occur in replenishment forthcoming from the main jet passage. In this manner the desired rich mixture for immediate "pick-up" from slow speeds is obtained.

Fig. 17 shows pictorially the manner in which the accelerating well comes into operation.

(*b*) The Accelerating Pump System

Certain engines, notably those employing long and/or cold-induction manifolding, require a greater supplement of petrol for acceleration purposes than could be reasonably supplied by means of an accelerating well. In such circumstances an accelerating pump is incorporated in the carburettor.

Fig. 15 shows a typical layout. The pump is interconnected with the throttle, so that when the latter is opened suddenly in order to accelerate the engine speed, petrol is forced out of the pump cylinder through a jet, to be forcibly added to the normal supply being issued to the main discharge jet.

An ingenious development of this system is employed in Stromberg carburettors. Study the details in Fig. 19. Note the inverted cylinder or pump sleeve, the upper end of which is attached to a pump rod. This

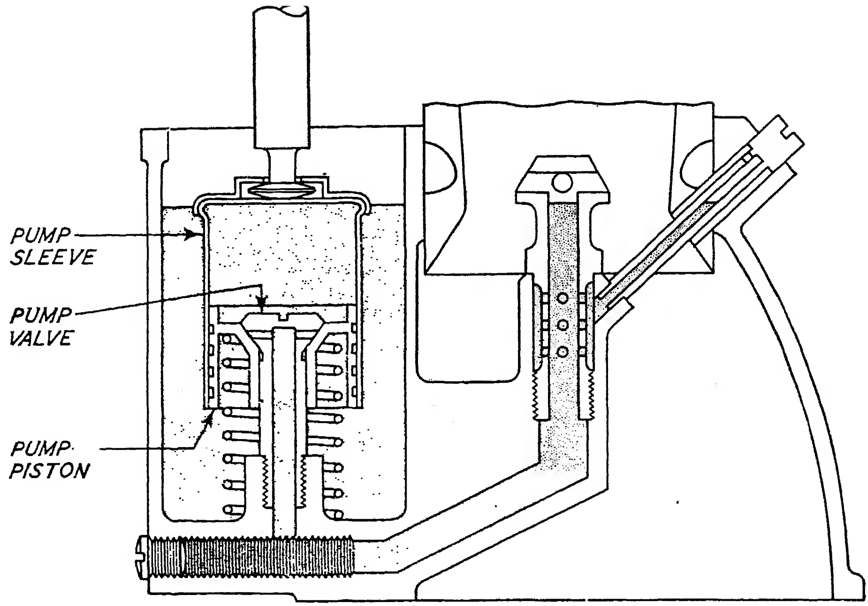


Fig. 19.—IDLING
Closed throttle, sleeve at top of stroke, piston seated.

rod in turn is connected to the throttle of the carburettor. Inside the cylinder is a piston which slides on a hollow stud. This stud is screwed into the main casting, so that its hollow centre connects with a petrol passage leading to the main discharge nozzle or to a separate discharge nozzle located just below the edge of the throttle valve.

The upper end of the stud is not unlike a small poppet valve in shape, with several holes in the wide face of the valve leading into the hollow centre. The valve seat is in the piston, which is held up against the valve by the pressure of the pump spring. The complete assembly is mounted in the float chamber.

Operation of the Accelerating Pump System

By a short series of illustrations it is possible to follow the operation of the accelerating pump system in various stages.

Fig. 19 gives a view of the pump system, when the engine is idling with throttle closed. The cylinder is now in the top position and the space within is filled with petrol. The throttle is now opened wide to obtain rapid acceleration.

Fig. 20 illustrates the changes that have taken place in the pump system just after the throttle was snapped open. The action of opening the

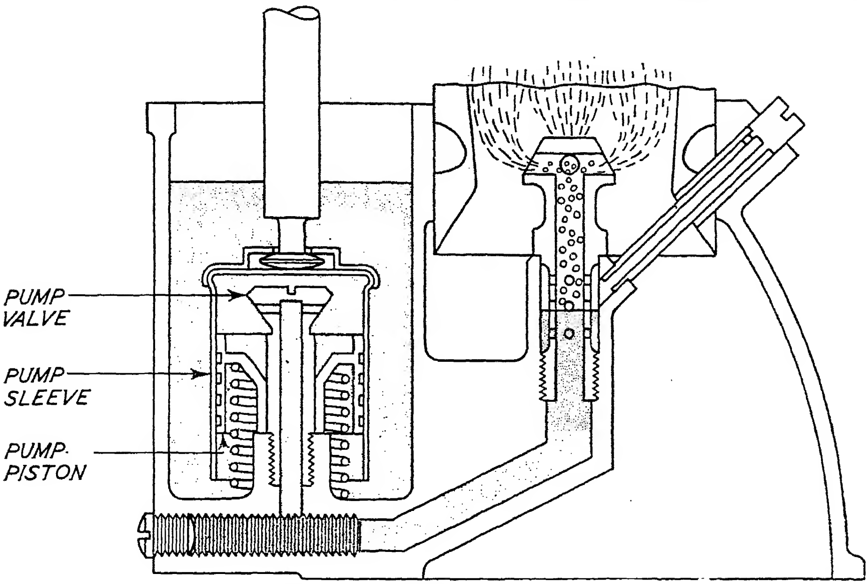


Fig. 20.—JUST AFTER OPENING THROTTLE

Full throttle, sleeve at bottom of stroke, piston off seat, and accelerating fuel being discharged.

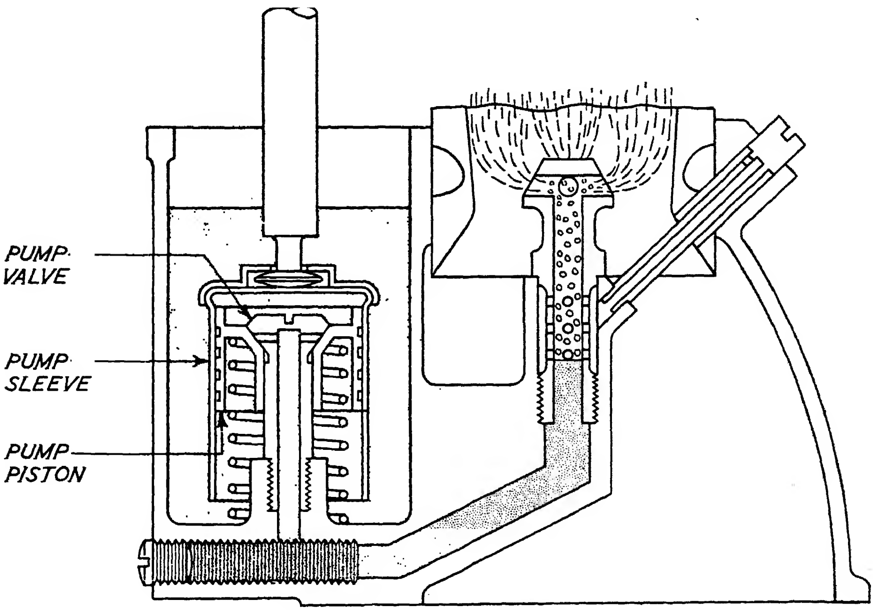


Fig. 21.—FULL THROTTLE

Sleeve at bottom of stroke, and piston seated.

throttle caused the pump rod to be pushed downwards owing to the interconnection mechanism. This in turn forces the pump sleeve downwards, and the pressure of the fuel inside will cause the pump piston to be forced downwards also. This will leave the pump valve open, and as the petrol in the cylinder is now under pressure, it will be forced out of the valve to the main discharge nozzle. The spring will now commence to assert its strength and push piston upwards.

This results in a continuation of petrol discharge through the pump valve to the discharge nozzle until the piston has risen high enough to close off the valve seat once more, as shown in Fig. 21. The accelerating system is then out of action.

The object of this arrangement is to provide a momentary spurt of fuel immediately on opening the throttle, to be followed by a sustained discharge for several seconds and thus ensure a prolonged accelerating period.

Only when the throttle is "snapped" open for rapid acceleration is the pump discharge required. It is not needed when the throttle is opened gradually. The system explained provides for these requirements. When the throttle is opened suddenly, the action of the pump system will be as already described. If rapid acceleration is not required, it is not necessary to use more petrol than is normally supplied by the main carburettor. Under these conditions the throttle is opened gradually.

This results in the fuel passing through the clearance space between the pump cylinder and piston, back into the float chamber, and not being forced out through the pump valve, as is the case when the throttle is "snapped" open.

When the throttle is closed again, the pump cylinder will be recharged with fuel, which is drawn from the float chamber through the clearance space between the cylinder and pump valve.

Another Type of Accelerating Pump

Another type of accelerating pump that may be encountered is that shown in Fig. 22. In this case a pump cylinder or sleeve is fastened to a boss at the bottom of the float chamber by a nut which encloses a small spring-loaded check valve. Into the cylinder is fitted a cup-shaped leather piston, and the assembly is operated by interconnection with the throttle.

It will be seen that the complete assembly is situated below the petrol level and that the top of the cylinder is open. Consequently, when the throttle is closed and the piston is pulled on its upward stroke, the cylinder will be charged by fuel being drawn past the leather piston.

Throttle Opened Quickly

When the throttle is opened quickly for acceleration purposes, the leather piston forces the fuel out of the cylinder through the check valve

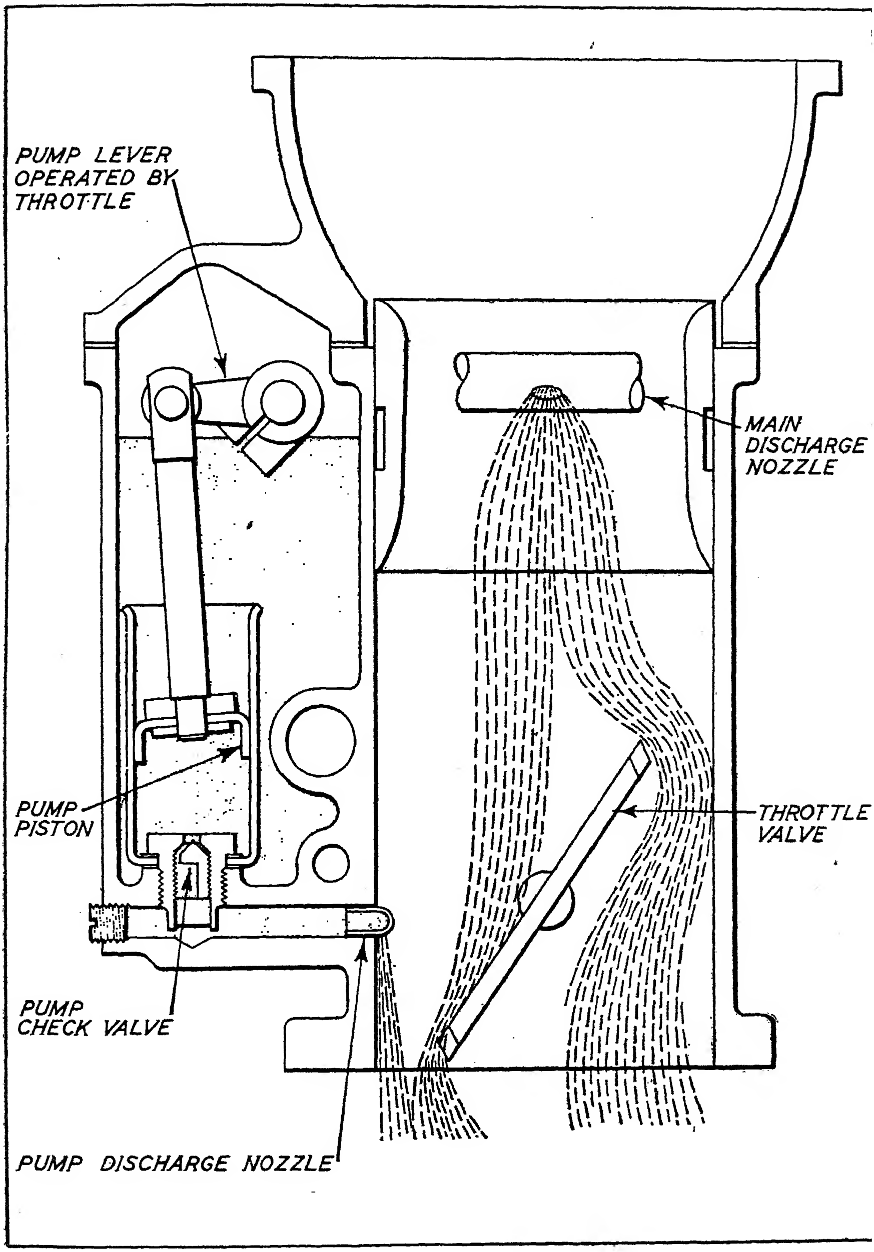


Fig. 22.—Accelerating pump with leather piston and check valve

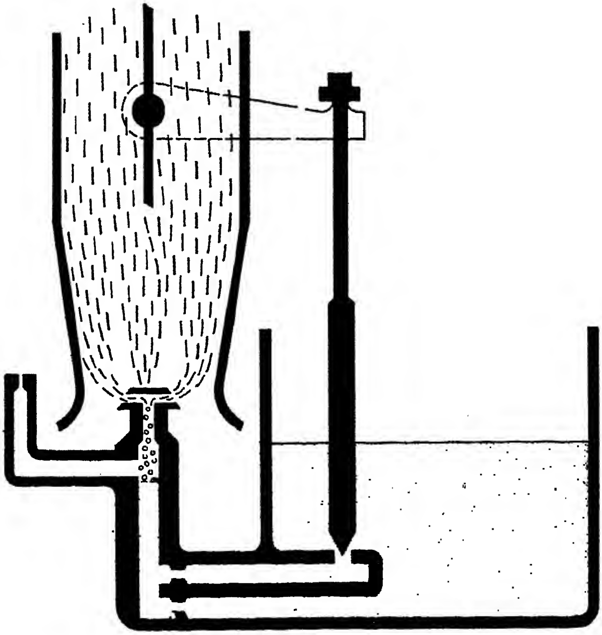


Fig. 23 (*left*).—NEEDLE-VALVE ECONOMISER OPERATED BY THROTTLE, WITH MAIN DISCHARGE JET

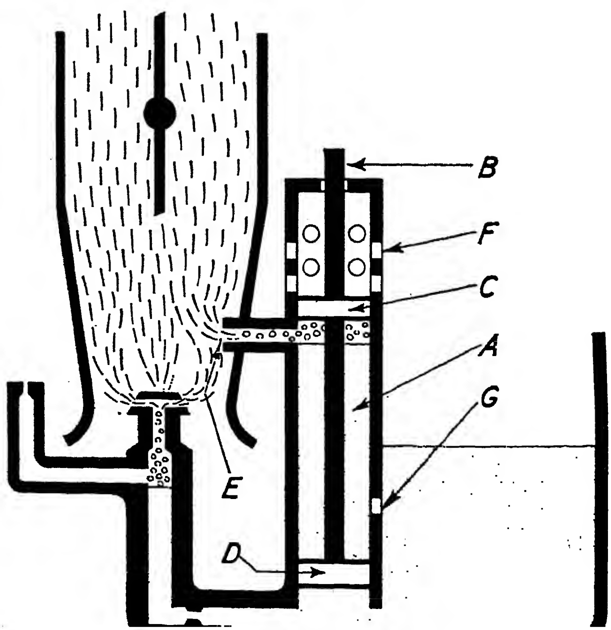


Fig. 24 (*right*).—PISTON-TYPE ECONOMISER OPERATED BY THROTTLE WITH MAIN DISCHARGE JET. FULL THROTTLE

to the accelerating discharge nozzle. From here it will be added to the normal carburettor supply to provide the desired richness for rapid acceleration.

Accelerating Pump Adjustment

Many factors are concerned with the eventual pump output, length of stroke, size of pump valve, capacity of cylinder, strength of piston spring, size of discharge channels or jets—all go to decide the amount of extra petrol that will be supplied for acceleration purposes. Actually, very few of these factors are adjustable or variable in the ordinary course of events. They are set by the manufacturers at the time of construction for the particular requirements of the engine to which the carburettor is to be fitted.

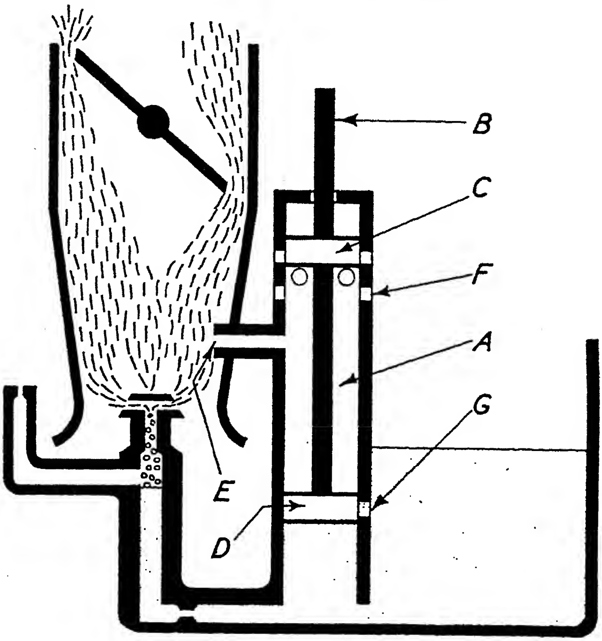


Fig. 25.—Piston-type economiser operated by throttle with main discharge jet. Part throttle (cruising)

The effects of the size and disposition of the various factors will be readily apparent, however. For instance, if the length of stroke is shortened, the acceleration period is also abbreviated. A larger pump valve will give a richer mixture ; the bigger the capacity of the cylinder the greater will be the output of the circuit. If the pump spring is weakened, the acceleration period will be longer but the richness less ; the smaller the channels or jets, the less rich will be the acceleration output.

All the parts mentioned must be kept clear of foreign matter and mechanism must be working freely.

The Economiser System

A further refinement is now introduced, namely, "the Economiser System." The object of this, as the title implies, is to ensure maximum economy. It is effective during part-throttle conditions. On such occasions a weaker mixture ratio can be employed than is normally forthcoming when the carburettor is set to give the richer mixture necessary for maximum power under full-throttle conditions.

Basic Principles of Economisers

This objective is quite simply achieved, but various forms of economisers are employed, and their basic principles will be described. Fig. 23 plainly illustrates a needle-valve type economiser. It will be seen that the main discharge nozzle is fed by the different channels from the float chamber. One channel is permanently open to the main discharge assembly, but the opening of the other is controlled by a needle valve.

Under part-throttle conditions the former channel only is feeding the main discharge nozzle and the desired lean mixture is obtained. Beyond a certain throttle opening, however, this mixture would be too weak to obtain the full power of the engine. It is made richer in the following manner : the needle valve controlling the secondary supply to the main discharge assembly is connected to the throttle lever, so that at a predetermined throttle position the valve is lifted sufficiently to enable the secondary channel to supplement the main channel supply to the jet assembly.

From this description it will be realised that "economiser" is a misnomer, for the arrangement "enrichening device" would be a more accurate description.

Another Type of Economiser

Another type of economiser is illustrated in Figs. 24 and 25. It provides alternative means of achieving the same object. It is the piston type and is operated by the movement of the throttle. In the case of the piston-type economiser, however, there is only one feed to the main discharge assembly. This supplies the fuel for early throttle openings. For full-power conditions a separate system entirely provides the full-throttle mixture strength.

This system comprises a cylinder A, inside which is a rod B with an upper piston C and a lower piston D. In the lower part of the cylinder A a drilling G is made below the petrol level. In the top part drillings F are made to the atmosphere. Finally, a discharge nozzle E leads from the cylinder to a position inside the choke tube in the vicinity of main discharge assembly outlet.

The rod B is connected to the throttle in such a manner as to cause the pistons to take up the positions shown in Fig. 25 when the throttle is only partly open. Under these conditions the lean mixture alone is required.

It will be seen that the lower piston D is now in a position that covers the fuel port G, and that the upper piston is above the air-release holes F. Now the discharge nozzle E projecting into the choke tube is under depression and a suction will be present in the cylinder A. This suction is instantly relieved, however, through the holes F, which are open to atmosphere.

The throttle is now moved to the wide open position and the inter-

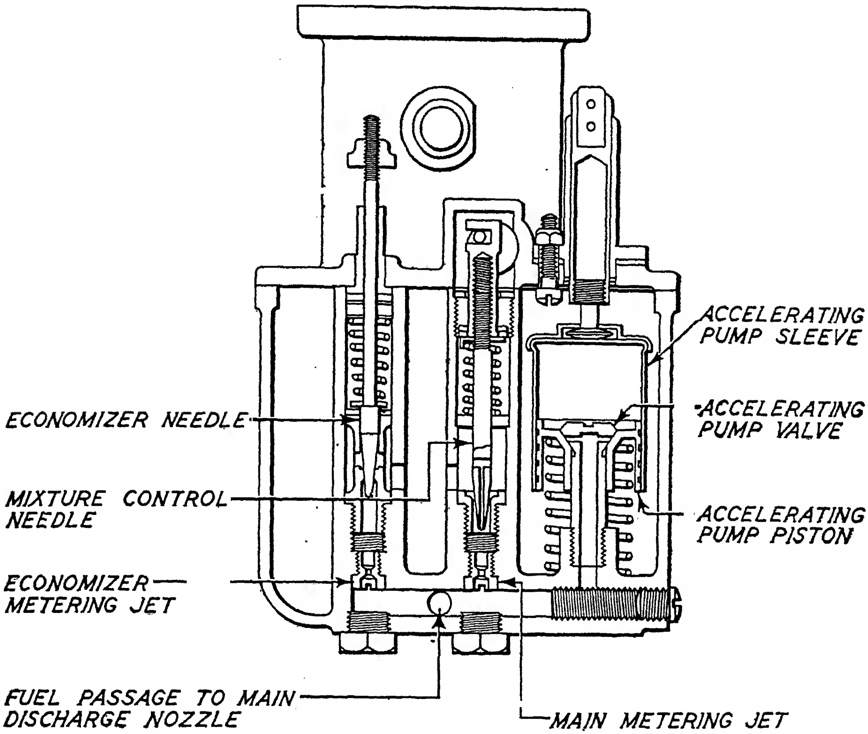


Fig. 26.—SECTION THROUGH STROMBERG NA–R9 CARBURETTOR

Showing needle-valve type economiser and mixture control, and accelerating pump.

connection mechanism with the piston rod B causes the pistons C and D to move to the positions shown in Fig. 24. The fuel port G is now open to the inside of the cylinder and the air release holes F are above the top piston. The depression or suction at the discharge nozzle G can no longer be relieved by drilling F.

The result is that the chamber A is now under reduced pressure, and petrol will be drawn in through the fuel port G and discharged from the nozzle E into the choke tube. In this way it augments the fuel that is leaving the main discharge outlet and so provide the necessary full-throttle mixture strength.

Needle-valve Economiser

The needle-valve economiser system is seen in Fig. 26 as it appears in an actual carburettor. The accelerating pump will be recognised on the right and the economiser on the left. The assembly in the centre may be disregarded for the time being.

The diagrammatic illustration, Fig. 23, is readily recognisable in Fig. 26. The economiser needle is located in the centre of a well that is

open to the float chamber by a drilling seen in the right-hand side of the well. The needle is spring-loaded and is tapered at the base to locate itself in the orifice of a metering jet positioned at the bottom of the well, when the throttle is in the closed position. At a predetermined throttle opening a forked lever on the throttle spindle engages a collar on the upper end of the economiser needle valve stem and lifts the needle out of the metering jet orifice.

Petrol will at once flow from the well through the economiser metering jet to supplement the normal fuel supply as already described.

Adjustments

The main adjustment concerns the throttle position at which the economiser needle is lifted. This can be varied by lowering or raising the position of the collar on needle-valve stem which engages with forked lever on the throttle spindle. The position varies with different engines, but the throtttle is usually between 25°–30° open when the valve is lifted. This can be said to correspond with an engine speed about 200 r.p.m. below that obtainable at full throttle.

A variation can also be made in the size of the economiser metering jet, if necessary. A smaller jet will reduce the extra supply of fuel to the main system and vice versa.

The parts must be kept clean and working freely at all times. Dirt in the jet or around the needle will seriously affect the operation of the economiser system. Similarly, if the needle is worn, the spring is weak, or any other factor is causing fuel to flow to the jet other than during the intended period, petrol consumption and engine performance are likely to suffer.

Piston-type Economiser

Complications arise when putting into action the basic principles of the piston-type economiser, described by Figs. 24 and 25. Figs. 27, 28, and 29 show the modifications that may be met. At first sight they may appear far removed from the simple Figs. 24 and 25, but keep those principles clearly in mind and the other drawings will be readily followed.

Idling Conditions

Fig. 27 shows the conditions that exist when the engine is idling with the throttle closed. It will be seen that fuel has entered the economiser from the float chamber through the economiser metering jet A. This jet at all times controls the amount of fuel passing through the economiser system. From jet A the petrol rises in the drilling B and uses the port C to flow into the economiser well D. From the well it passes through another drilling into the passage E. Under the idling conditions shown in Fig. 27 the petrol will fill passage B and the economiser well D and rise into passage E to the same petrol level that exists in the float chamber.

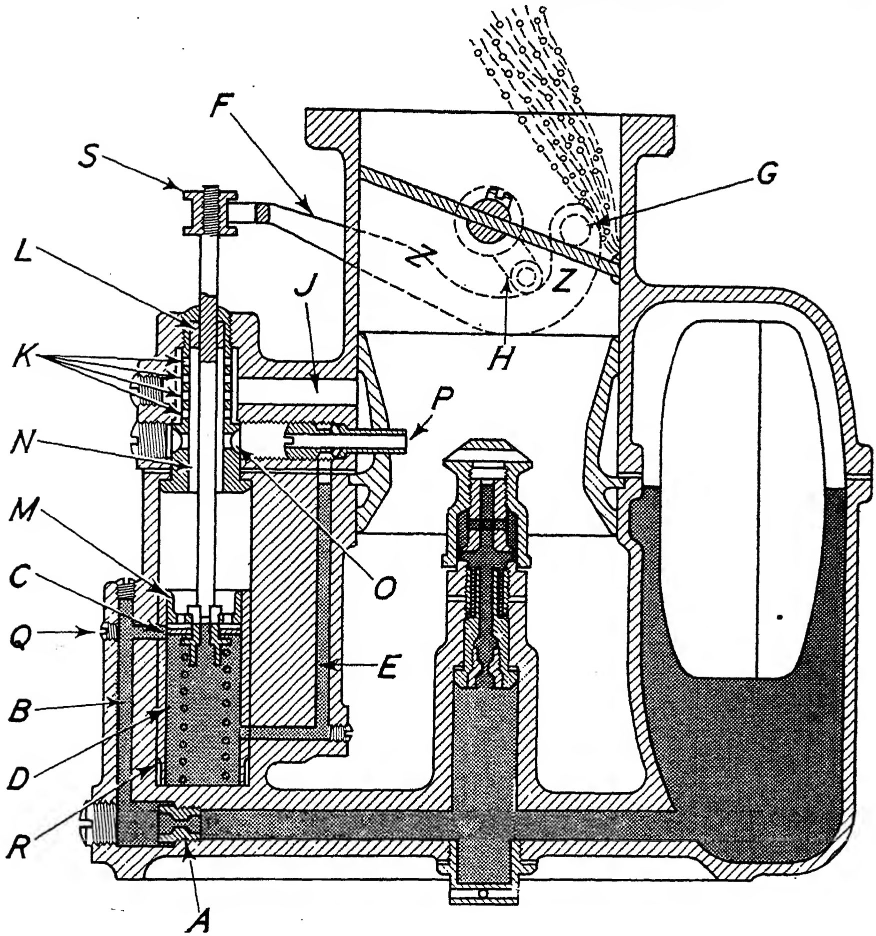


Fig. 27.—Showing conditions that exist when the engine is idling with the throttle closed

The economiser proper consists of two pistons L and M working in a sleeve N and a bushing R. The upper piston L works to regulate the air bleed to the economiser, and the lower piston M operates on the fuel flow. The air bleed at practically atmospheric pressure enters the passage J from behind the choke tube and passes through the ports K to the interior of the economiser. It goes to the discharge nozzle P through the common fuel and air passage O. This air bleed serves to relieve the suction existing at part throttle, so that fuel will not be drawn past the piston M (clearance must be allowed for the operation of the piston) or through the passage E.

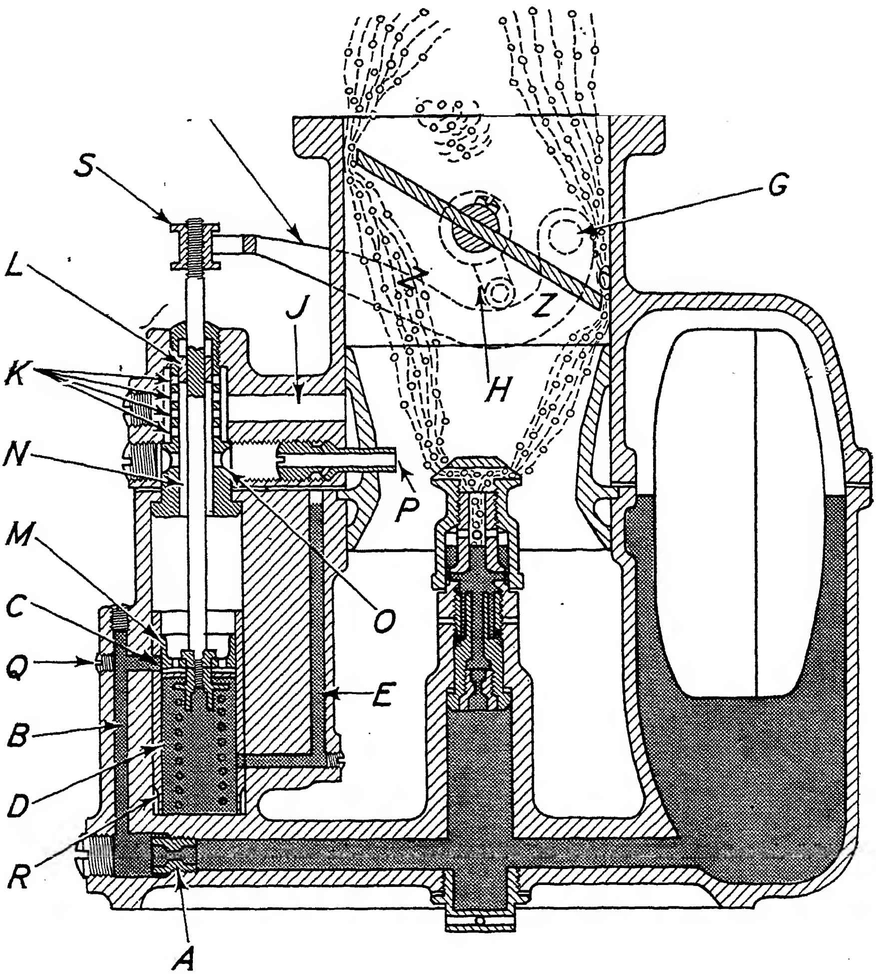


Fig. 28.—ILLUSTRATING THE OPERATION OF THE ECONOMISER SYSTEM (1)

How Economiser Operates

To follow the economiser system in its operation, it is now necessary to refer to Fig. 28. The throttle is opened to accelerate the engine, and this action causes the cam lever F, pivoted at G, to move downward against the action of the roller H. Lever F is connected to the economiser at S; consequently, the downward movement of the lever F also forces the economiser downwards. The piston M has also fallen and covered the port C to prevent more fuel flowing into the well, but piston L at this stage has not moved sufficiently to prevent air entering the economiser

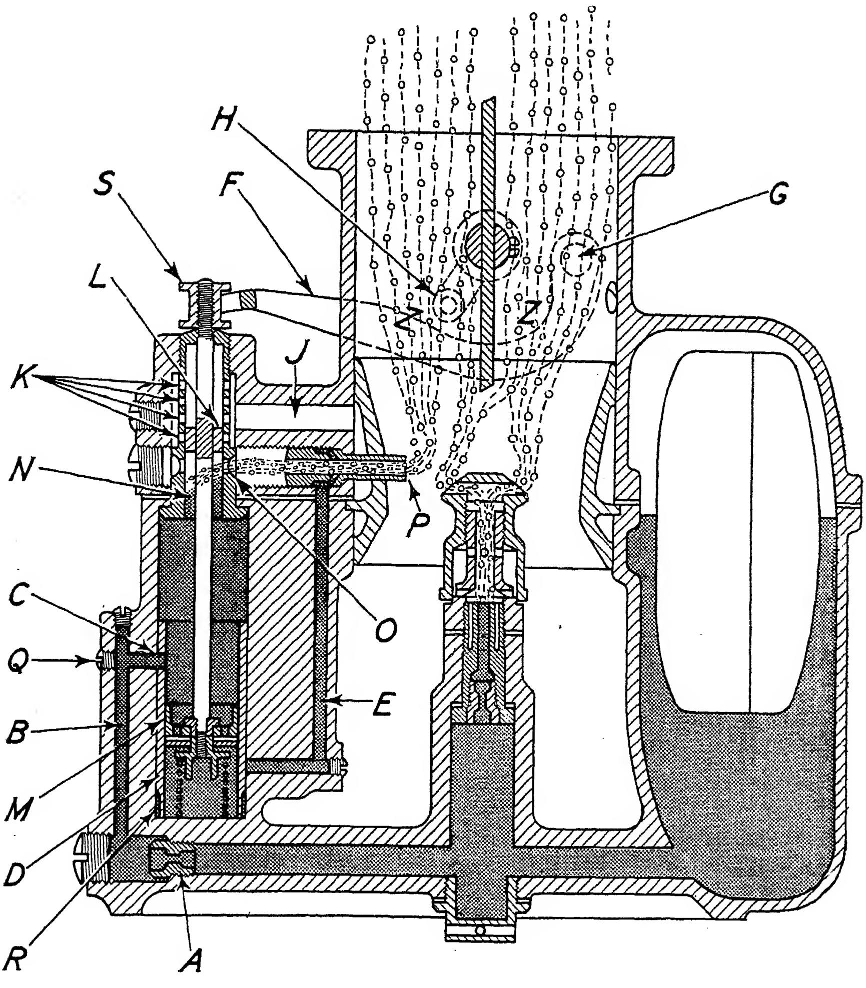


Fig. 29.—Illustrating the operation of the economiser system (2)

through the port J and drilling K. Consequently, any partial vacuum or suction on the discharge nozzle P will be released through these air drillings.

The next stage is shown in Fig. 29. Throttle is now wide open and the interconnection mechanism has forced the economiser to operate fully. It will be seen that the port C has become uncovered again, but this time the fuel will pass into the economiser above the piston M. The discharge nozzle P is now under depression or suction, and as there is now petrol in the economiser above piston M, this fuel will be discharged from the

nozzle P to supplement the normal output from the main discharge outlet. The piston L now covers the openings (K) to atmosphere, with the result that there is no release to the suction from nozzle P, which is consequently now fully concentrated upon the fuel in the economiser.

In actual fact it is an emulsion of petrol and air that issues from the nozzle P and not neat petrol. This of course is very desirable, as it assists in the general atomisation of all the fuel that passes to the engine. The emulsification of the supply from the economiser system is obtained owing to the fact that there is a clearance between the piston L and its guide that is sufficient to allow a small air leak through the drilling K past the piston L. The air from this leak mixes with the fuel at O, and the emulsion of air and petrol then proceeds to the nozzle P and to discharge into the choke-tube area.

Adjustment to Economiser

Again, it must be emphasised that under normal circumstances no adjustments are likely to be necessary. The different variables are arranged at the time of production to suit the particular requirements of the engine to which the carburettor is fitted. Nevertheless, the description of operation just given was intended to make apparent what adjustments would be possible should certain symptoms arise to indicate that all was not well with the economiser system.

As an example, it was shown that the jet A controlled the supply of petrol that was allowed to pass from the float chamber to the economiser system. Should there be symptoms that the supply was too generous (heavy fuel consumption) or was insufficient (loss of maximum power), then a smaller economiser jet would be indicated in the first instance or a larger one in the second case.

Again, it may happen that the discharge from the economiser system was coming into operation earlier or later than required. Should it operate early, sluggish engine performance during early or mid-throttle conditions and heavy petrol consumption would be observed. If it operates late, power loss will occur. To prevent these possibilities, it is important to observe the movement of the piston M. Referring back to Fig. 28, it will be seen that M has moved downwards and covered the port C. With the piston in this position the throttle is opened sufficiently to admit a No. 51 drill between the throttle edge and the barrel of the carburettor.

Now turn to Fig. 29. It has been seen that the fuel flow through the economiser system starts when the upper edge of piston M passes the edge of passage C. This corresponds to a throttle opening of 22°. Bear in mind that the throttle when closed forms an angle of 20° with the carburettor flange, and as a consequence the angle between the throttle and the flange will be the sum of these two angles (42°) when the economiser comes into action.

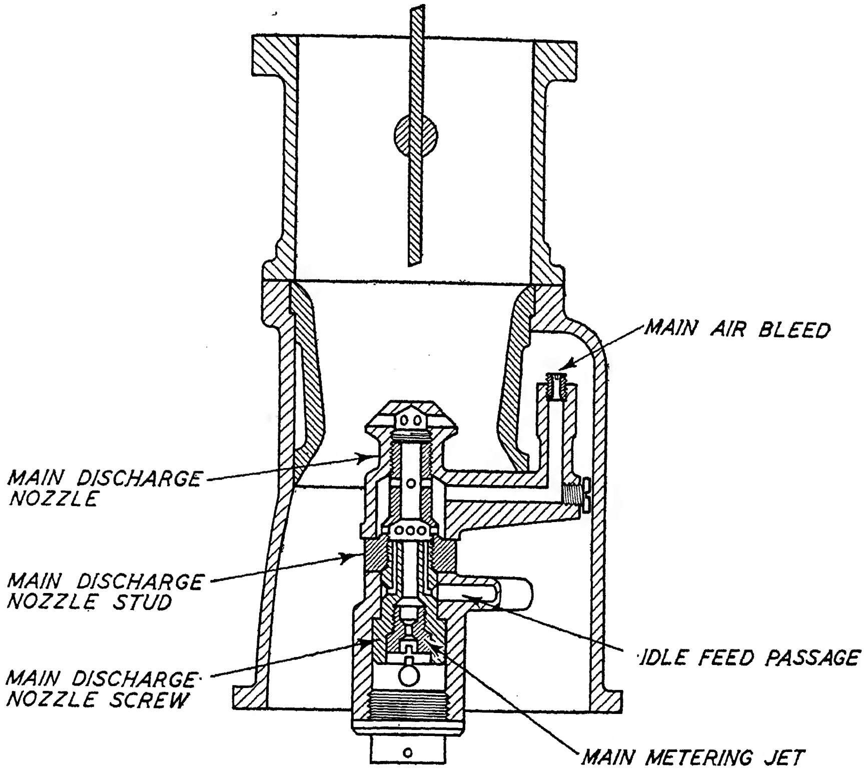


Fig. 30.—Three-piece main discharge assembly

Any adjustments necessary to make the economiser action conform to these requirements must be made to the connector S. This can be moved up and down the rod in conjunction with the cam lever F to give the required position of the piston M at specified throttle opening.

Apart from these adjustments, it is of course essential to keep all parts clean and working freely. There must be no undue wear of the pistons L and M, and the spring beneath M must retain its tension. Ensure that there is no lost movement in the throttle lever to economiser system mechanism, and keep all passages, particularly the air drillings J and K, free from obstruction. Should these drillings to atmosphere become choked, it will be realised that piston L becomes non-effective, and suction at nozzle P will be felt in the economiser and extract petrol at periods when it is not required.

Accelerating Pump Effect of Economiser

The description utilising Figs. 27, 28, and 29 follows with reasonable faithfulness the basic principles of Figs. 24 and 25. One complication

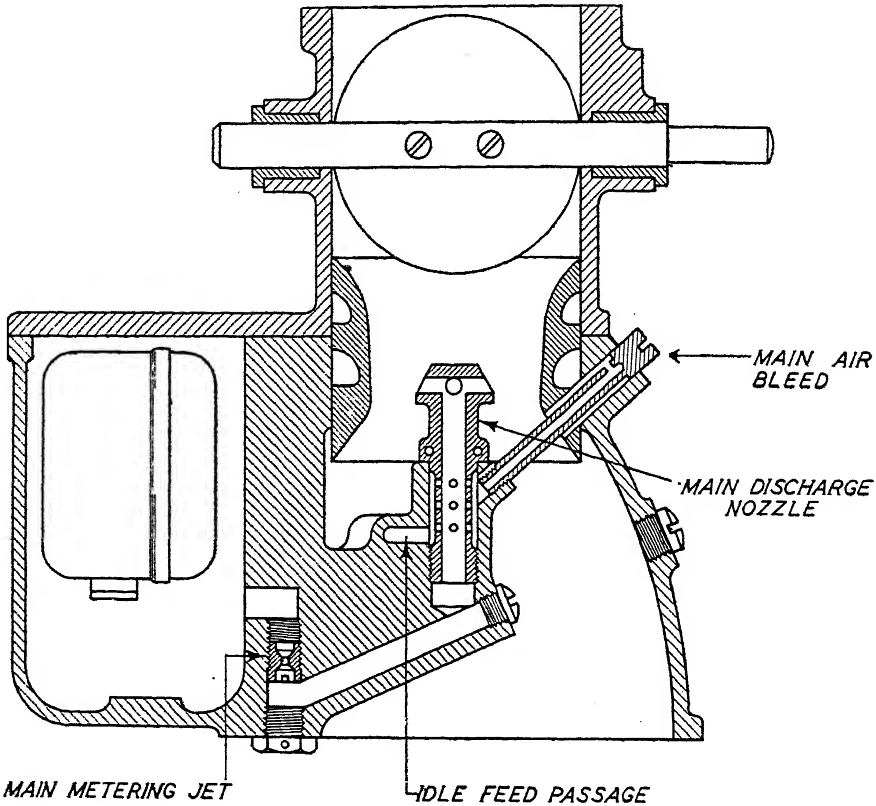


Fig. 30A.—Main discharge assembly

demands detailing, however. The function of channel E has yet to be explained. So far only the economiser effect has been described, and the action considered only at specified throttle positions. It will be realised, however, that as the piston M moves downwards, the fuel in the space D beneath will come under pressure. The only release for this is the drilling E. Consequently, petrol in chamber D will be forced out and up the passage E, discharging itself through the nozzle P into the choke tube area. This provides a charge for accelerating purposes regardless of the speed of throttle opening.

The nozzle P is so designed that the accelerating charge of the fuel enters from an annular groove, and is directed towards the venturi by several holes drilled at an angle between this groove and the centre hole of the discharge nozzle. This arrangement prevents fuel from entering the space above the piston M during a rapid opening of the throttle.

The Main Metering System

When the throttle is opened beyond the idling position, depression or suction is felt at the outlet of the main discharge assembly. This at once brings into action the main metering jet system, as described in early pages and illustrated by Fig. 11. This drawing actually showed the basic principles only, but Figs. 30 and 30A show the principles actually incorporated in a carburettor.

The depression now present at the main discharge nozzle causes petrol to be drawn from the assembly. That immediately below the nozzle will be taken up instantly and the assembly will then be open to atmosphere from the main air bleed in accordance with the fuel-compensating principles previously detailed. Petrol will now be drawn from the float chamber and measured by the main metering jet. This calibrated fuel then meets the air from the main bleed and proceeds as an emulsion to the discharge nozzle. It is then drawn into the choke or venturi tube, where it is completely atomised by the inrushing air stream, and by which it is then carried past the throttle valve into the induction manifolding and engine cylinders.

The wider the throttle is opened the greater will be the depression or suction felt at the main discharge nozzle (presuming engine load is constant). It will be remembered that pressure in the float chamber is remaining constant, so it follows that a greater supply of fuel will result to allow the engine speed to increase.

The Altitude Mixture Control

A problem with which all manufacturers of aero carburettors have to contend is the fact that the higher the altitude attained by the aeroplane the less will be the pressure, temperature and density of the atmosphere. The effect of this upon normal carburation procedure is to reduce engine power and to cause the fuel ratio to become richer. Power loss results by the decrease in air density, reducing the weight of the air charge taken into the engine. The percentage of power loss is about proportionate to the weight of charge and decrease in air density. Similarly, the mixture becomes richer at a rate inversely proportionate to the square root of change in air density.

In order to compensate for the change in mixture, a mixture control is provided in all Stromberg Aircraft Carburettors. The mixture supplied by the carburettor may be made leaner by any one of the following three methods :

(1) By reducing the effective suction on the metering system.

(2) By restricting the flow of fuel through the metering system.

(3) By admitting additional air into the induction system through an auxiliary air entrance.

Each of these three methods has been employed in Stromberg Aircraft Carburettors.

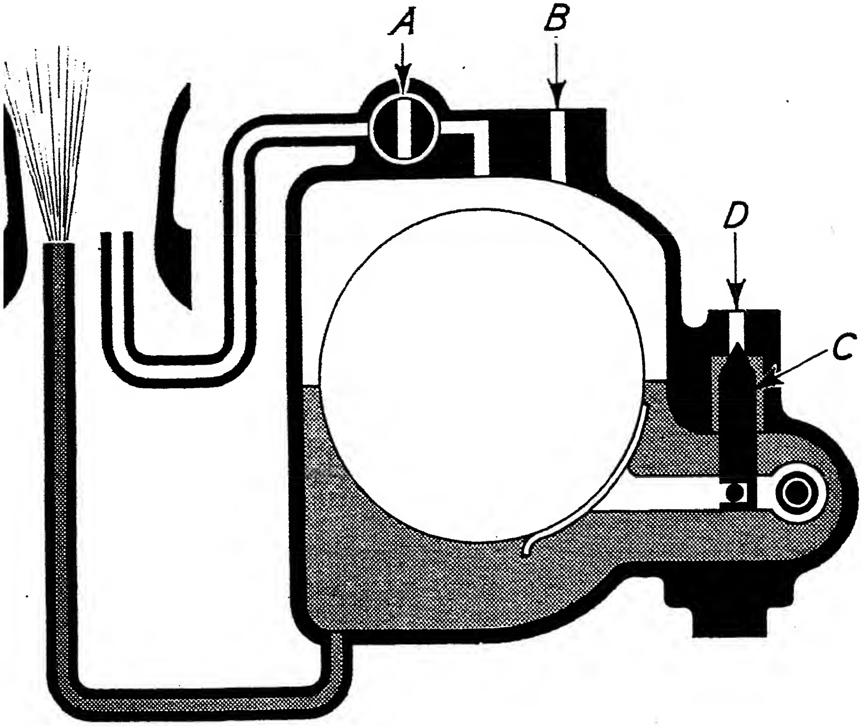


Fig. 31.—Mixture control valve in suction passage
Full rich position.

Float-chamber Suction Control

This type of control to reduce the fuel flow is sometimes known as "back-suction control." To understand it closely a careful study should be made of the basic carburation principles detailed in the first part of this article. It will be remembered that a description was given of how fuel was forced from the float chamber out of the jet because the pressure at the jet outlet was less than that present over the fuel in the float chamber itself. The pressure in the chamber remained constant whilst the pressure at the jet outlet varied according to throttle opening to provide more or less fuel as required. With "back-suction" altitude control, there is a modification to this principle. The depression or suction on the jet outlet continues to vary, but a control is now placed upon the pressure that is present in the float chamber. Obviously, if this pressure is reduced, then the fuel output for a given depression on the jet outlet will also be reduced.

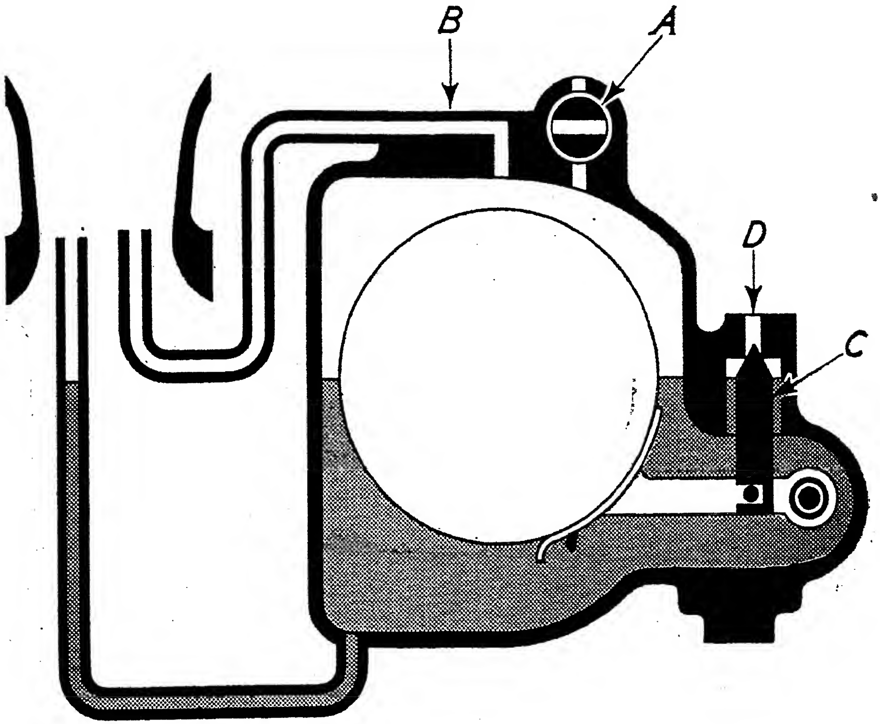


Fig. 32.—MIXTURE CONTROL VALVE IN PASSAGE TO ATMOSPHERE
Full lean position.

How the Necessary Weakening of Mixture Under Altitude Conditions is Obtained

Figs. 31, 32, and 33 show by simple diagrams how the necessary weakening of mixture under altitude conditions is obtained. A simple jet is shown leading from the float chamber to the choke tube. There are two sources (A and B) of air supply to the chamber. One is open to atmosphere and the other is open to the same suction to which the outlet of the jet is subjected.

Take Fig. 31 first. Of the two openings A and B to the float chamber, A is connected to the choke tube and B is open to atmosphere. A valve is incorporated in the " A " line, and in Fig. 31 it is turned to cut off the pressure from the choke area. Consequently, the float chamber is only open to atmosphere and the normal carburation principles apply. Under these conditions the output of the carburettor would be rich when the aeroplane attains altitude. To correct this the altitude mixture control is turned from the " full rich " position to open the valve. The result of this action will be to impose some of the suction that is present at the jet

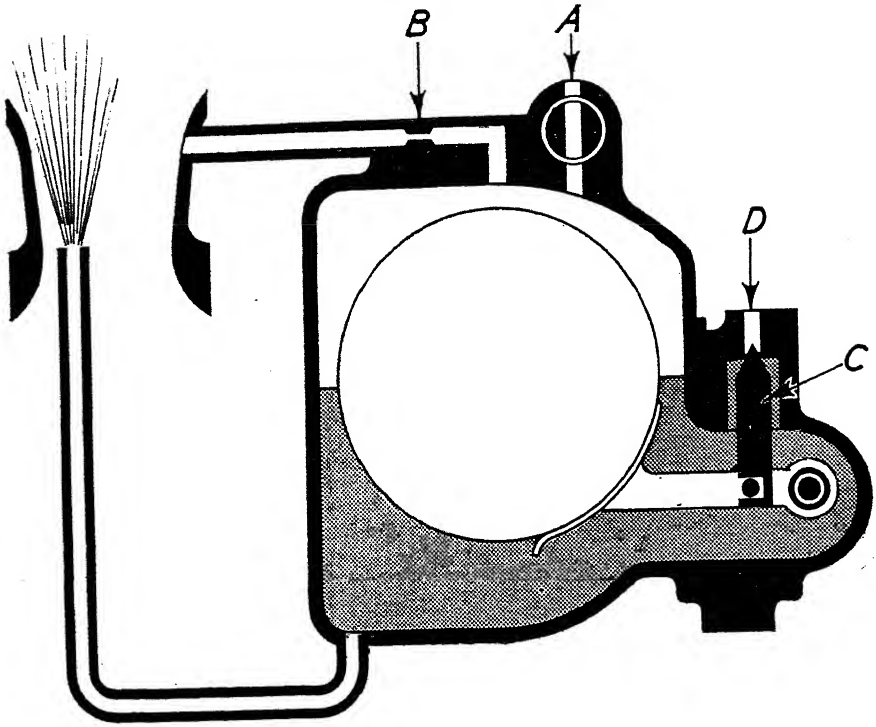


Fig. 33.—ARRANGEMENT USED IN STROMBERG CARBURETTORS

Mixture control valve in passage to atmosphere. Restriction in suction passage. Full rich position.

outlet upon the float chamber. This reduces the pressure in the chamber and results in a reduction of the fuel flow from the jet.

" Cut-off " Position

In Fig. 32 the valve A is this time placed in the " open to atmosphere " drilling, and is shown in the " cut-off " position. It will be realised that the same pressure exists now at the jet outlet and in the float chamber. Consequently, no fuel at all will flow because the suction is the same on both sides of the jet system. This, then, is the extreme " lean " position that can be obtained with this type of control in which there would be no fuel flowing. As the valve is opened, however, air is admitted to the float chamber, thus creating a pressure that will cause fuel to flow from the jet. This will increase as the valve is opened, until the mixture control is in the full rich position, when the valve will be wide open. There would, naturally, be suction above the fuel in the float chamber, when the valve is in the extreme lean position of Fig. 32, which would tend to draw

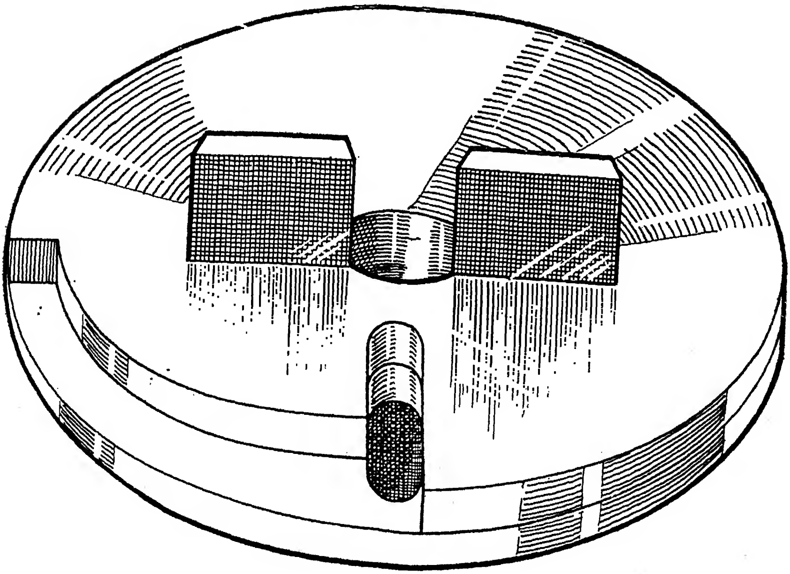


Fig. 34.—ENLARGED VIEW OF ALTITUDE CONTROL DISC VALVE AND PLATE ON WHICH IT SEATS

more fuel through the needle seating D, but provided the float was large enough, the needle C would remain tight on its seating and maintain the normal height of petrol level in the float chamber.

The Suction Connection

In actual construction the suction connection to the float chamber is not taken from the same position in the choke tube in which the jet outlet is placed, but at a point where the suction is always less than that at the narrowest part of the choke tube where the jet outlet is positioned. This must be in a wider section of the choke tube, as shown in Fig. 33, and furthermore a restrictor of fixed size is placed in the actual passage. The object of this is to avoid the possibility of fuel supply ceasing because of the common pressure that can exist at jet outlet and in float chamber, as described above. With this arrangement the valve A may be completely closed without entirely stopping the flow of fuel. When the valve is in intermediate positions, the pressure in the float chamber will not be equal to the full suction on the jet, neither will atmospheric pressure be attained. The pressure will be something between the two, depending upon the degree of valve opening. With the valve H in a fixed position, the pressure in the float chamber will always be the same percentage of the

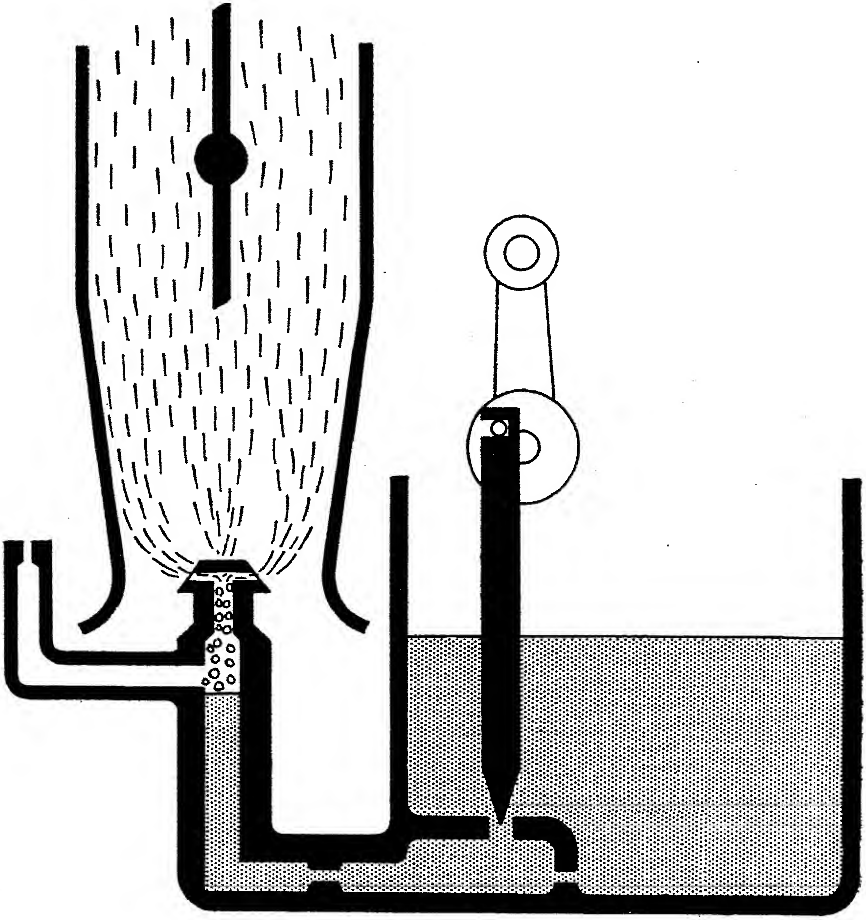


Fig. 35.—Needle valve type mixture control, with main discharge jet

suction at the discharge nozzle, regardless of how this suction may vary. So the action is uniform at all speeds.

Altitude Control of Disc Valve

In order to obtain a control that is not too sensitive to adjust, the closure of the valve must be rapid at first and then more gradual. This effect is obtained by using the altitude control disc valve illustrated in Fig. 34. From this it will be seen that two plates rotate against each other. One plate has a slot hole to coincide in the open position of the valve as shown with a similarly shaped slot in the other plate. In the case of the latter, however, the slot is not extended to the full length of

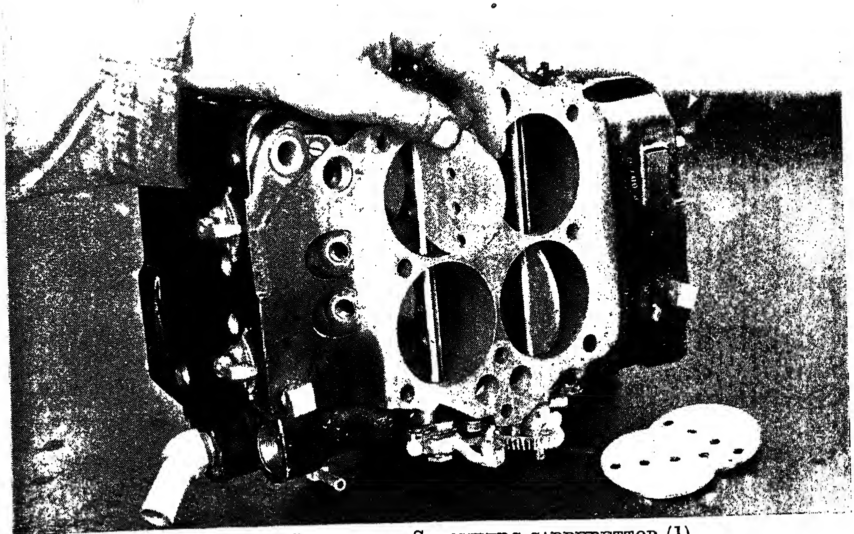


Fig. 36A.—SERVICING A STROMBERG CARBURETTOR (1)
Fitting the butterfly valve.

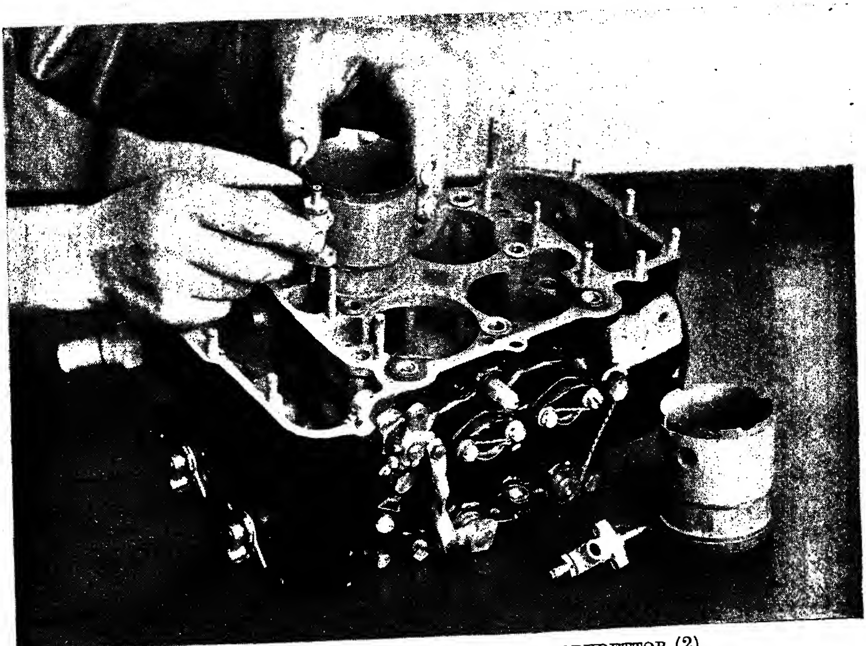


Fig. 36B.—SERVICING A STROMBERG CARBURETTOR (2)
Fitting venturi and main air bleed.

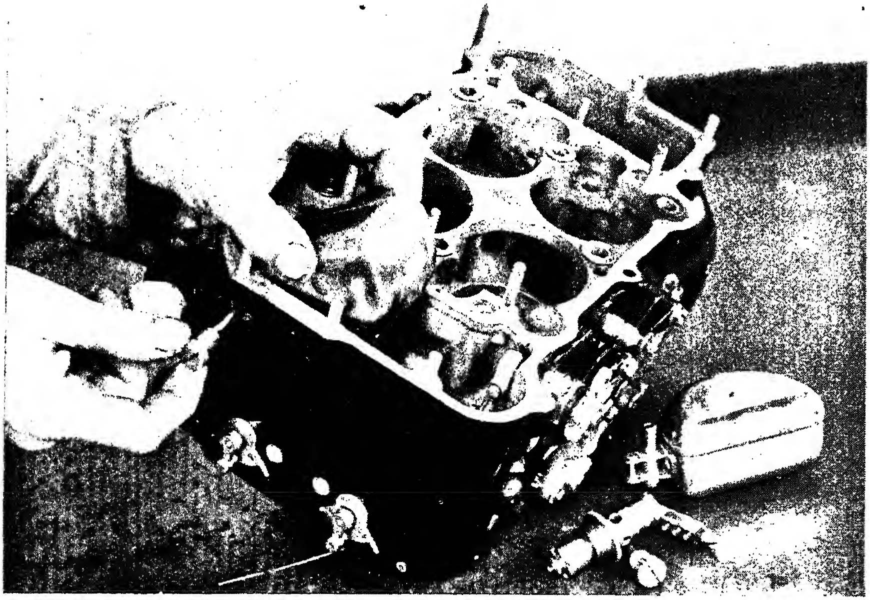


Fig. 36c.—Servicing a Stromberg carburettor (3)
Fitting the float chamber.

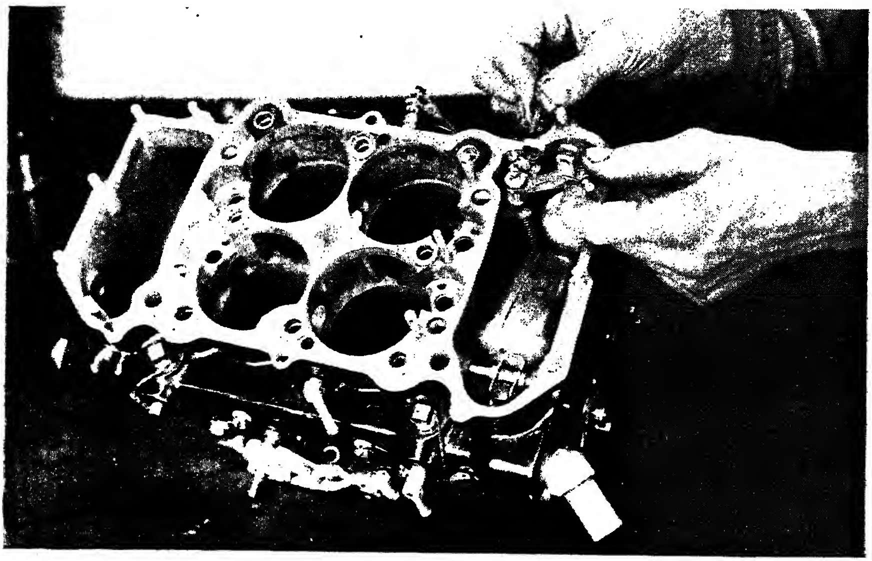


Fig. 36d.—Servicing a Stromberg carburettor (4)
The accelerator pump plunger with stop for economiser setting.

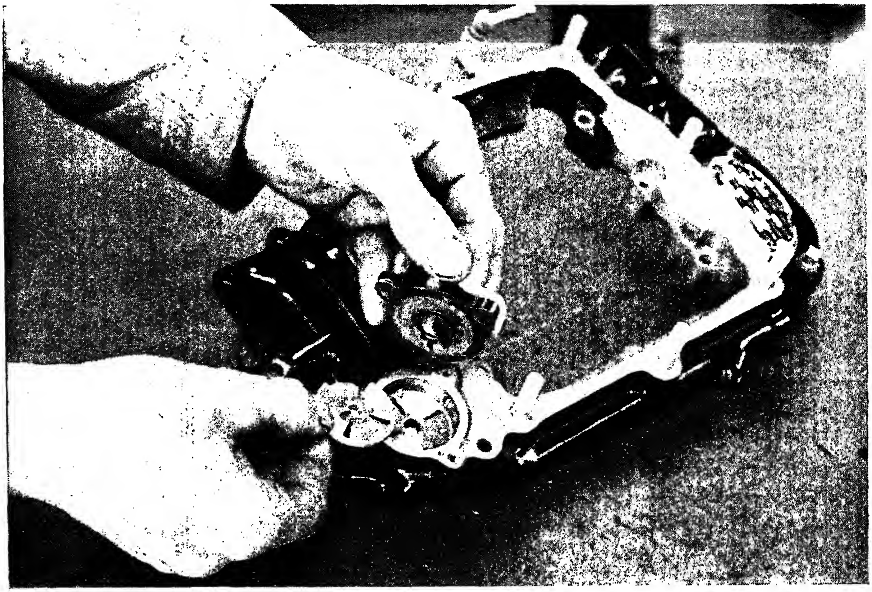


Fig. 36E.—Servicing a Stromberg carburettor (5)
The mixture control and plate valve.

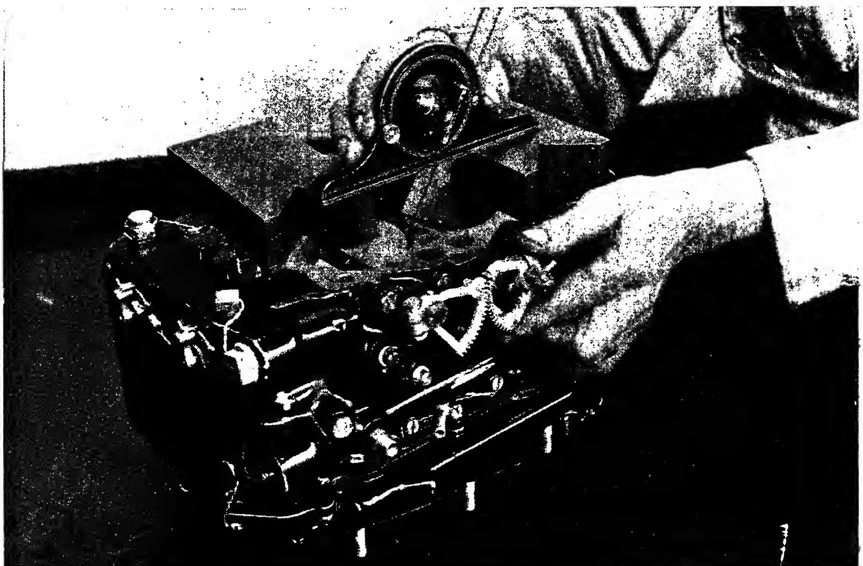


Fig. 36F.—Servicing a Stromberg carburettor (6)
Checking the economiser setting.

the slot beneath, but cuts away to the edge of the plate in a widening arc. Consequently, as one plate rotates, the immediate action is to cover a large proportion of the slot on the other plate. As the first plate continues to rotate, the remainder of the slot is gradually covered. This type of valve produces changes in the mixture ratio directly proportional to the valve movement.

Needle-valve Control

Fig. 35 illustrates another type of altitude control—the needle valve. In this case the control is made to the fuel supply to the main discharge jet. Fuel is fed to the jet in the normal manner from the float chamber, but a needle is placed so that it can restrict the flow. When the mixture control is in the " full-rich " position, the needle will be completely clear of the main drilling between the float chamber and the main discharge nozzle.

To lean out the mixture under altitude conditions, the control is operated so that the needle enters the fuel drilling and causes a restriction to the petrol flowing from the float chamber to the main discharge nozzle. This will naturally weaken the fuel output of the carburettor.

A small bypass hole, from the float chamber to the fuel passage, permits some fuel to flow even though the needle valve is completely closed. The size of this bypass opening determines the range of control.

Uniformity of Control

It will be noted that all the control methods detailed maintain a uniformity of the mixture range. Any given setting of the altitude control reduces the suction or the fuel flow through the jet by the same percentages at all engine speeds. Since the delivery of the jets bears a constant ratio to the suction, any given setting of the control has a substantially uniform effect upon the mixture at all engine speeds, during which the main jet is in operation.

Range of Altitude Mixture Control

The range of the mixture control is usually designated in terms of altitude. This means that a carburettor, having a correction range of 20,000 ft., will give the same mixture ratio at this altitude, with the mixture control set at " full lean," as it would give at sea-level conditions with the control set at " full rich."

It will be clear from the explanation which appears on page 103, under the heading " The Altitude Mixture Control," that the increase in height would have a tendency to produce a richer mixture, owing to the fact that the air entering the carburettor intake is considerably less dense at 20,000 feet than is the case at sea-level, thus the proportion of petrol to air becomes greater unless the necessary adjustment is made by some form of mixture control.

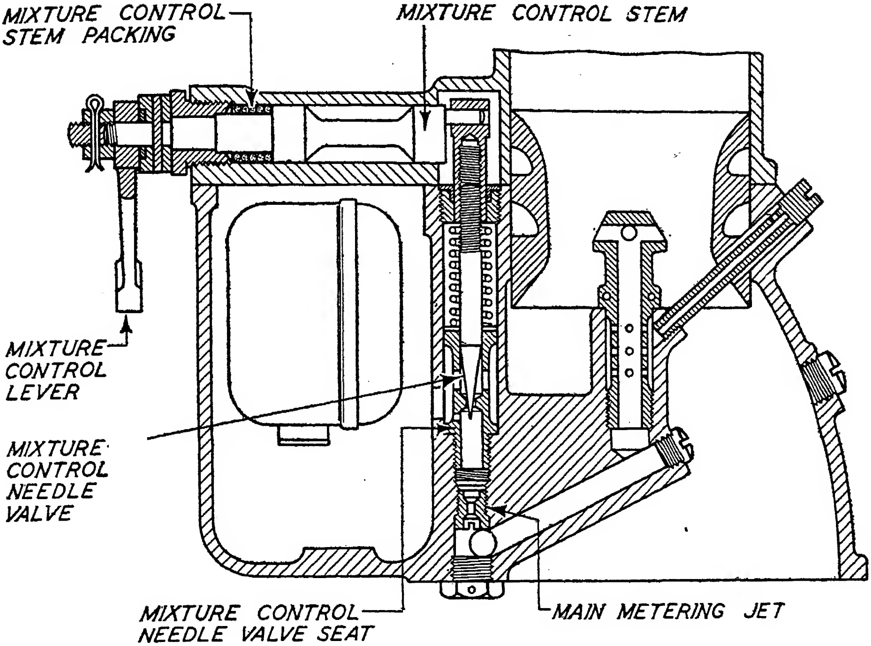


Fig. 37.—NEEDLE-VALVE TYPE OF MIXTURE CONTROL

If a metering jet setting is used which gives a mixture richer than necessary on the ground, with the idea of using the mixture control to correct for this condition, the remaining control available for altitude use will be less than if the ground-level jet setting was correct with the control "full rich."

The float-chamber suction type and the needle-valve type of mixture controls have a correction range of approximately 25,000 ft. altitude. After the limit of mixture-control correction has been reached, the aeroplane can ascend 5,000 to 6,000 ft. higher before the mixture will become rich enough to cause the engine to lose power, and several thousand feet more before the engine operation becomes excessively rough.

Atmospheric Vents

The pressure of the airscrew blast is often an appreciable percentage of the difference in pressures at the jet outlet and in the float chamber that causes fuel flow in the manner described earlier. Consequently it is very important that whatever the pressure disturbance caused by the airscrew blast, it should operate equally at the jet outlet and in the float chamber, in order that the fuel flow will be responsive only to the difference in pressure resulting from the flow of air through the carburettor.

To ensure this, the air release vents to the float chamber or the mixture-

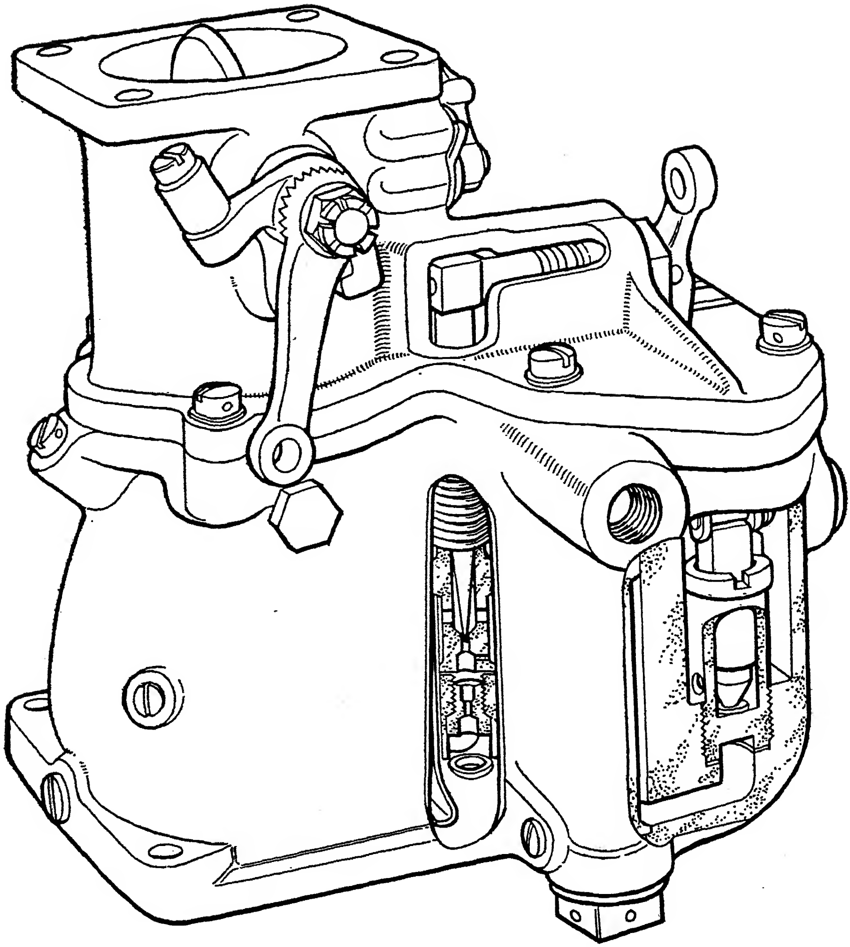


Fig. 38.—Mixture control and float needle valve assembly

control openings are brought to the air entrance of the carburettor. Any pressure disturbance resulting from the airscrew blast or the forward movement of the aeroplane is thereby balanced equally on the jet outlet and in the float chamber.

The air intake attached to the carburettor may cause turbulence or irregular flow of air into the carburettor. It will be realised that such conditions may cause different pressures to exist at various locations in carburettor air intake.

In order to obtain an average of these pressure valves in the float

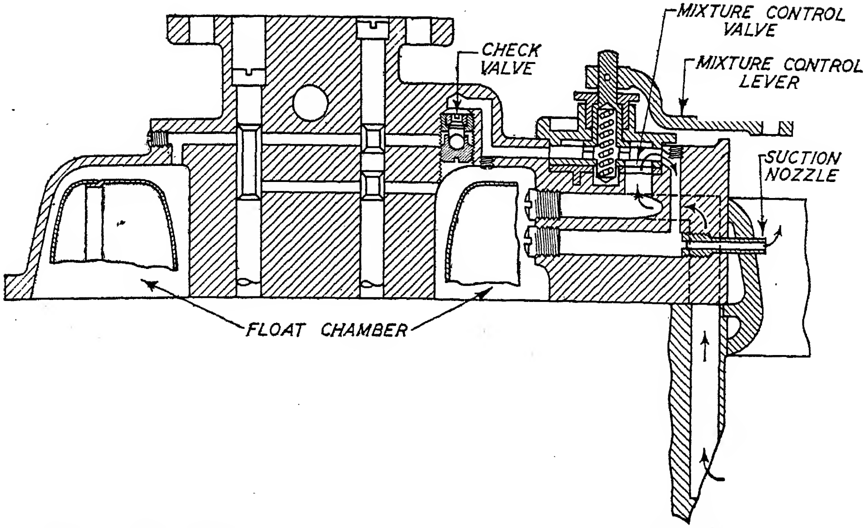


Fig. 39.—DIAGRAMMATIC DRAWING OF BACK-SUCTION TYPE OF MIXTURE CONTROL

chamber, the vent passage to this part is (in some models) opened into an annular space formed by a groove cut in the outside of the venturi (or choke tube). This will be seen illustrated many times in diagrams throughout this article. Fig. 13 is a typical example, but shows the air bleeding from around the venturi to the idling metering system and not to the float chamber.

The groove cut into the venturi is connected to the air intake by four slots. This arrangement allows the use of air intakes of various designs without affecting the metering characteristics of the carburettor. Whatever slight depression may exist in the air entrance is transmitted to the float chamber. For this reason a manometer connected to the float chamber during dynamometer tests may show some depression with either type of mixture control in the " full-rich " position.

Turning from the diagrammatic Figs. 31, 32, 33, and 35 to Figs. 37, 38, and 39, the needle-valve and back-suction type altitude mixture controls can be seen in use on actual carburettors.

The needle valve and seat are in series with the main metering jet between the float chamber and main discharge nozzle. As a result, the fuel flow through the main metering jet is reduced when the needle is lowered into its seat.

The needle is operated by an eccentrically located pin in a shaft to which the mixture-control lever is fastened. This shaft, as Fig. 37 shows, is provided with a packing gland near its outer end. This is to prevent fuel leakage when the carburettor is in the inverted position.

In the " full-lean " position, the needle should touch the seat. In the

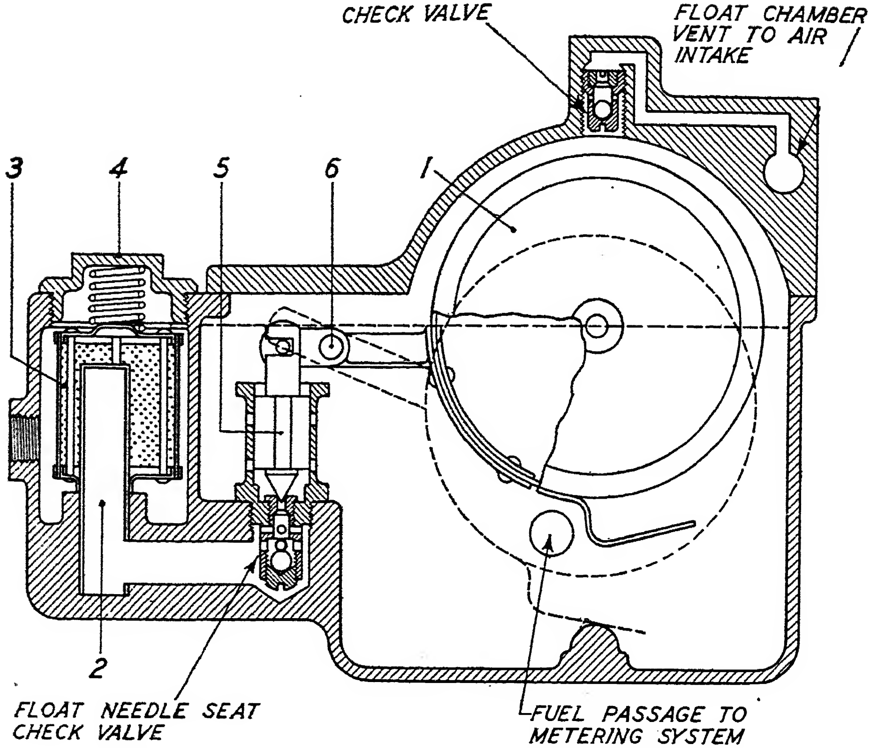


Fig. 40.—Typical Stromberg float mechanism construction

" full-rich " position, the needle is raised off the seat. The area around the needle in the " full-rich " position is larger than the area of the metering jet, so that the size of the metering jet determines the quantity of the fuel passing through the main metering system.

" Back-suction " Type

Fig. 39 shows details of the construction of the " back-suction " type altitude mixture control.

The operation of this control is exactly as described in the general basic principles section and illustrated by Figs. 31–34.

The suction nozzle is located above the throat of the venturi, or choke tube, and is connected to the space above the flat disc valve. A large passage leads from an opening in the valve to the air intake of the carburettor. Consequently, when operating at cruising or full-throttle speeds, there is a flow of air through the mixture-control chamber but not through the float chamber.

The mixture-control chamber is connected to the float chamber

through several passages and a check valve. This valve is open during normal flying conditions, but closes when the aeroplane is flown upside down or during any other manœuvres which have the tendency of lifting the pilot off his seat. The effect of this is also to prevent fuel from flowing into the mixture-control system and making the mixture excessively rich. The method of venting the two float chambers together, as shown in Fig. 39, is used to prevent fuel getting into the mixture-control system during manœuvres that would otherwise cause it to do so. The full appreciation of this method will be realised when a study has been made of the "float-mechanism" section that follows.

Fuel Lever Control

Foolproof operation of the float-chamber mechanism of any carburettor is of primary importance. How much more is this so where aeroplane carburettors are concerned: certain latitudes are permissible when units for cars or trucks are under consideration, but the refinements demanded from aeroplane carburettors by flying conditions permit of very little compromise.

In the first place, the fuel flow from an aeroplane carburettor should be subject to no other force than the suction resulting from the air flow through the carburettor. A separate constant-level reservoir or float chamber must be provided between the main petrol tanks and the metering system of the carburettor. Fig. 40 shows the normal design of float chamber utilised in many Stromberg aeroplane models, and the action is as follows:

When the float chamber is empty, the float (1) is in the position shown by the dotted lines. Petrol is then admitted from the supply line to the fuel inlet (4). From here it passes into a small chamber, in the centre of which is placed a filter (3). Passing through this filter into the passage (2), it meets the float-needle seat check valve. This valve will be open, so the petrol continues its course through the cage of the needle valve (5) into the actual float chamber.

Petrol will continue to flow, and as it rises in the float chamber the float will lift by reason of its buoyancy. It will continue to do so until it reaches the predetermined level shown by the straight dotted line in Fig. 40. When this level has been attained, the float (1) will be in the position illustrated.

It will be seen that there is an arm on the float (1), attached to the end of which is the float needle (5). Using the pivot (6) as a fulcrum, the arm will cause the needle (5) to be lowered on to its seat as the float (1) rises with the petrol. When the normal level has been reached, the needle (5) will be fully on its seat, and petrol can now no longer pass into the float chamber.

When the engine is running, petrol will flow away from the chamber to the metering system through the fuel passage seen in Fig. 40. The

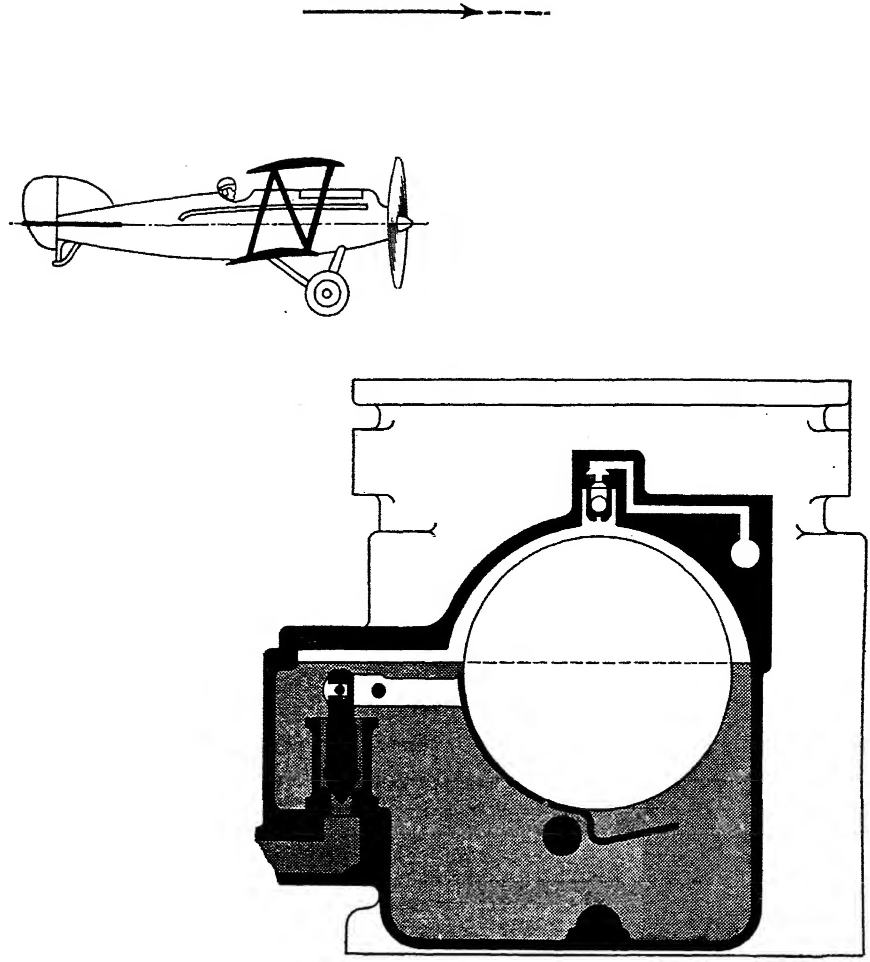


Fig. 41.—Level flight
Normal feed to jet, normal float action.

petrol level and the float will naturally fall below the normal level, and as the needle is once more lifted off its seat, petrol will resume its flow into the float chamber. The needle valve does not continually open and close in this manner whilst the engine is running, but takes up a definite position that will permit just enough petrol to flow into the float chamber to compensate for the fuel that is being extracted by the metering system.

Fuel Pressure

From this description of the float mechanism it will be realised that the pressure of petrol against the action of the float-needle seat check

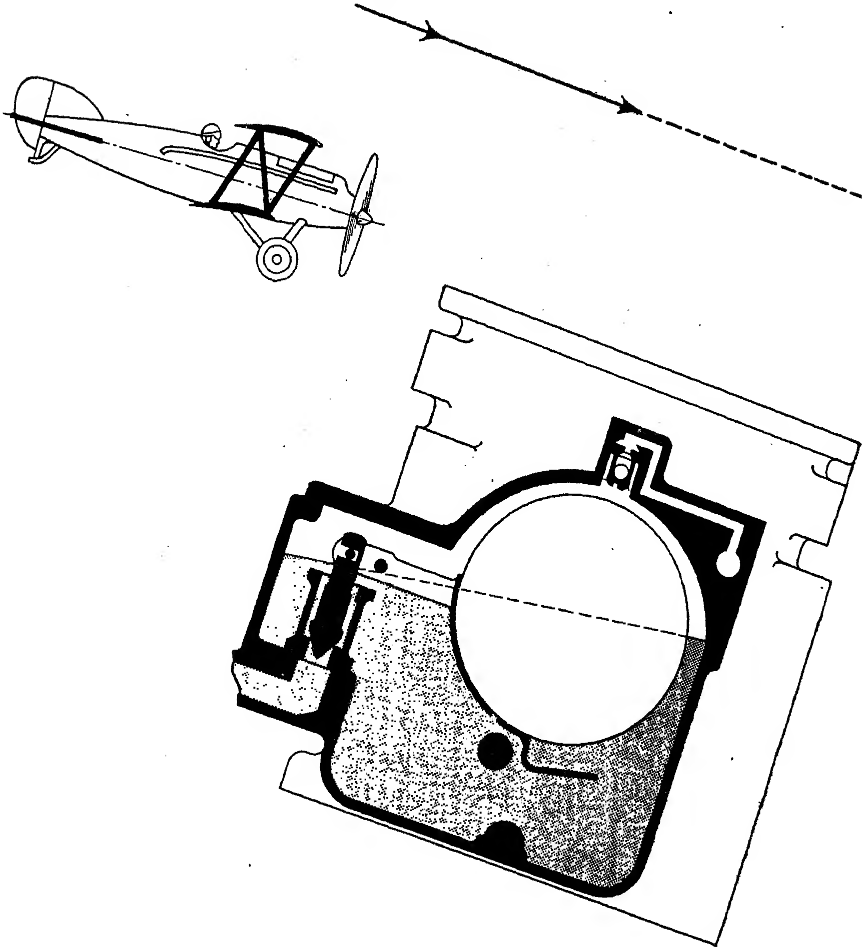


Fig. 42.—DIVE
Normal feed to jet.

valve is of utmost importance. If pressure is insufficient, then the feed to compensate for the extraction by the metering system will be insufficient. Should the pressure be excessive, it will overcome the resistance of the float and the needle and seat mechanism, and so cause the level to be higher than that predetermined as being required by the particular engine.

When feed to the carburettor is by fuel pump, a pressure of 3 lb. per square inch is recommended for service use. It will be realised, however,

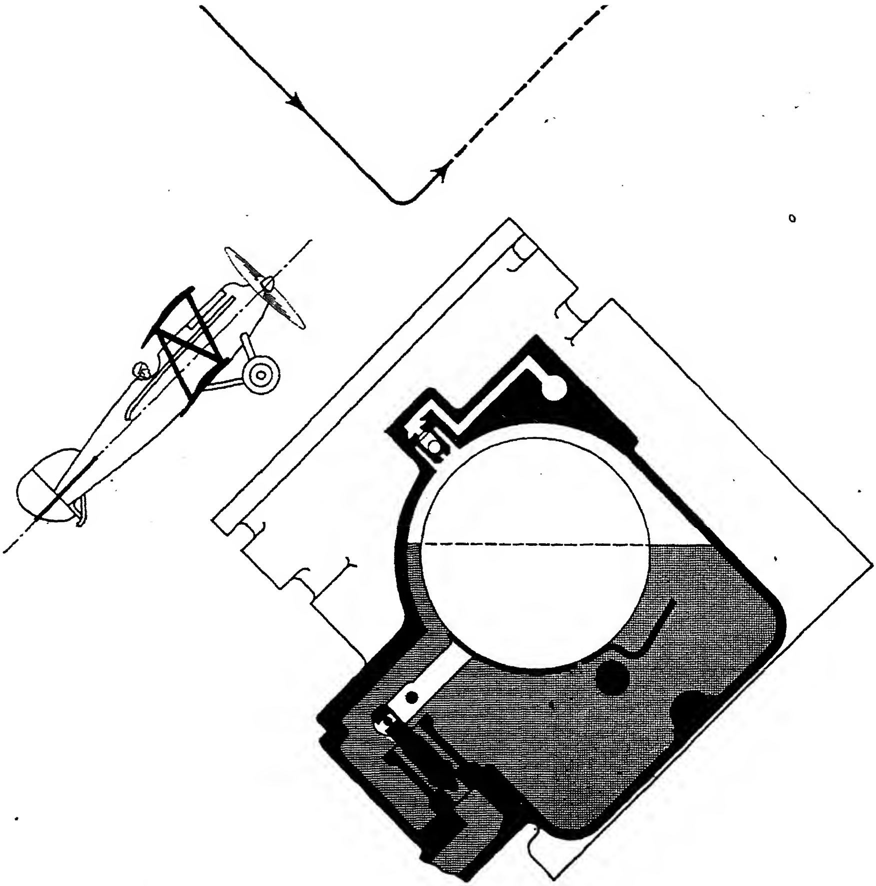


Fig. 43.—Zoom following dive or continuous steep climb
Normal feed to jet.

that no hard-and-fast rule can be made. The pressure will depend upon the particular requirements of an engine.

Special float-needle valves and seats may be installed for use should gravity-feed systems be employed with fuel heads of 78 in. (2 lb. per square inch pressure) or less. A tag indicating "gravity feed only" is attached to the carburettor when these seats are used.

On any gravity-feed fuel systems it is very important that the fuel-line sizes are large enough to maintain effective fuel heads or pressures when operating at full throttle opening. Usually a flow, as measured at the open end of the fuel line at the carburettor or 50 per cent. greater than the normal flow, will maintain an adequate pressure at full throttle.

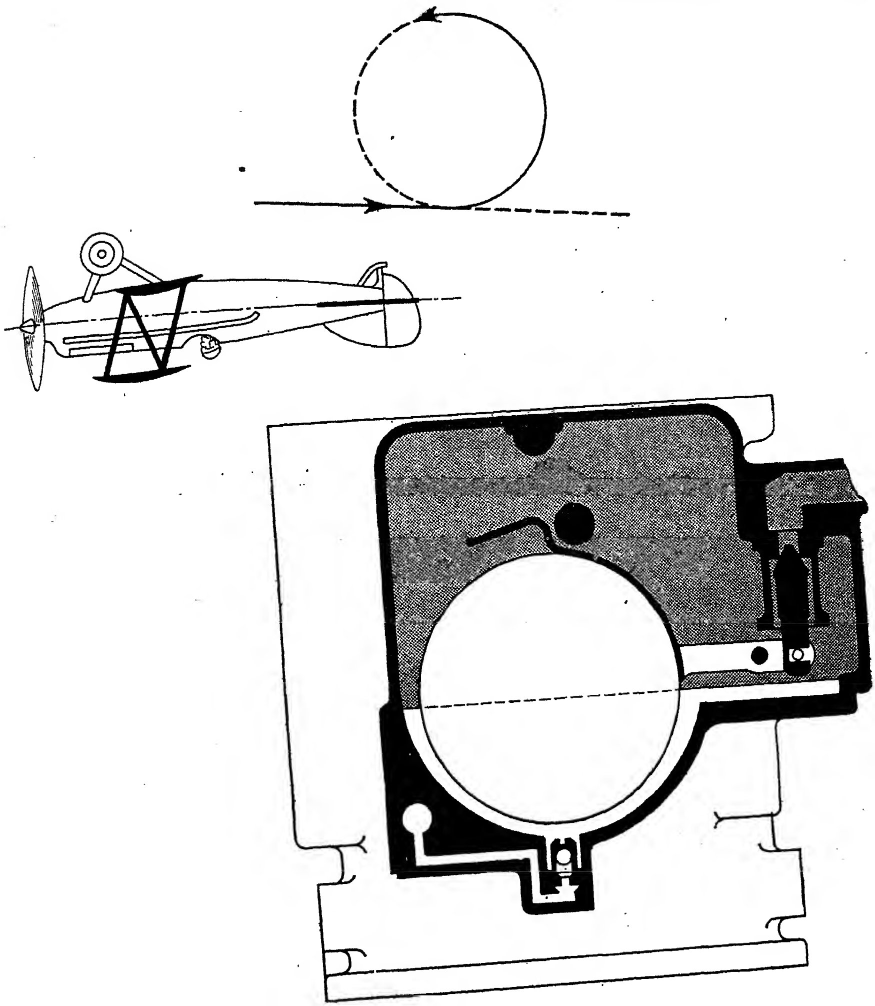


Fig. 44.—Loop without stall
Normal feed to jet.

Float Action During Manœuvres

The behaviour of the petrol in the float chamber, the manner in which it maintains its supply, and the methods adopted to prevent flooding during widely varied manœuvres of the aeroplane is always a fascinating subject. A chapter in the *Stromberg Manual of Aircraft Carburettors* describes this subject in a very clear manner as follows :

" The operation of the float mechanism and the position of the fuel during different manœuvres of the aeroplane depend, not only on gravity,

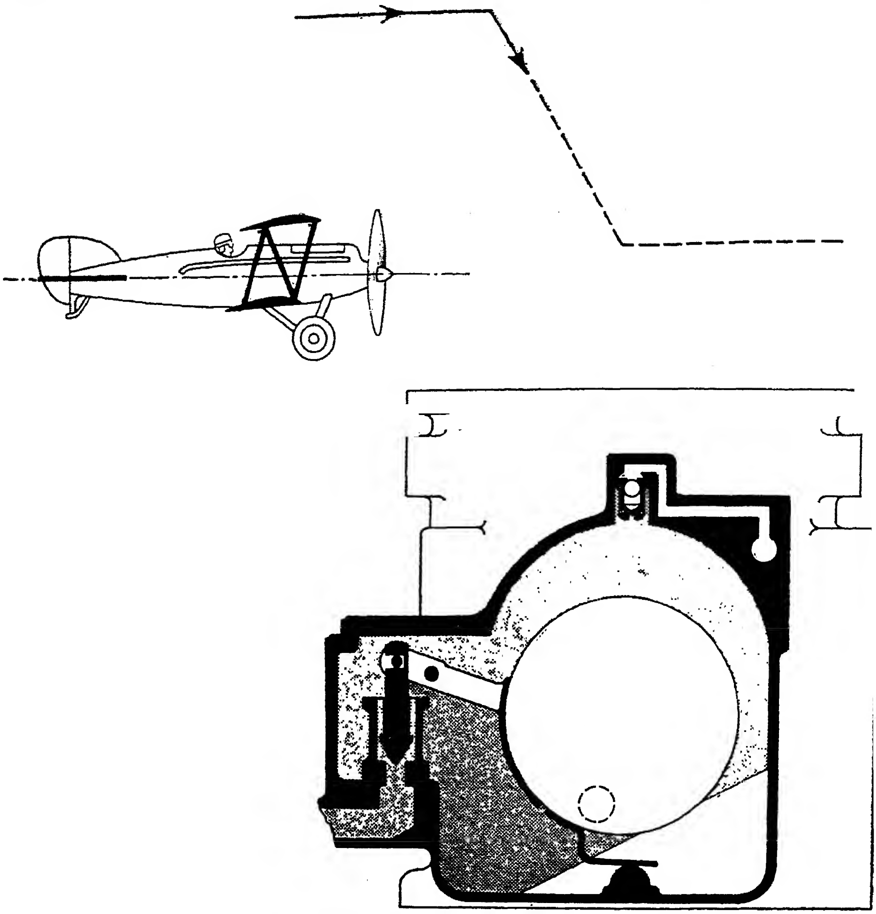


Fig. 45.—" AIR POCKET " OR START OF DIVE

Float action reversed. Normal feed to jet if gravity fuel system or check valve on needle valve seat are used.

but also upon the motion and position of the ship. The motion of the aeroplane involves inertia and, during certain movements, centrifugal force. The position of the plane determines the position of the outlets from the float chamber relative to the earth.

" It is necessary that the float mechanism should operate positively at all angles and positions where power is demanded from the engine, and that it should not permit leakage of petrol in other positions.

" Figs. 41–46 show the approximate position of the fuel in the float chamber during normal level flight and during some of the commonly executed manœuvres. The crew of the craft are acted upon by the same forces that affect the fuel in the carburettor. If the pilot is resting on

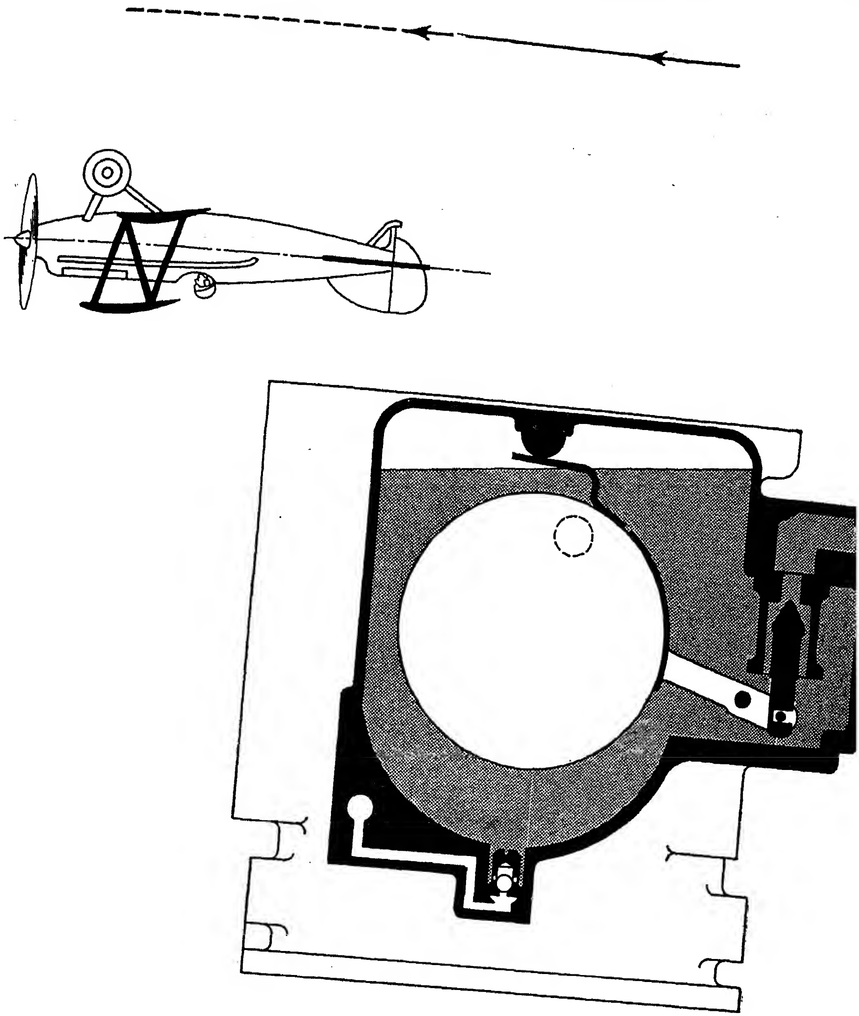


Fig. 46.—Upside-down flight
Float action reversed. Continuous feed to jet if fuel pump is used.

the seat, forced to lean hard against the back or sides of the seat, or tending to slide forward, the fuel in the carburettor will shift in the same direction, whilst the float action will be normal. These conditions exist in a climb, dive, side-slip, barrel roll, or loop executed without stalling, as shown in the diagrams. From these it will be noted that the passage leading to the metering system (shown by a black or dotted spot) is always covered with petrol. Consequently, the fuel feed to the engine is never interrupted by starvation.

"If the position or motion of the aeroplane is such that the pilot tends to be lifted off the seat and be supported by the belt, the same forces will cause the fuel to go to the top of the float chamber. This can occur when a violent gust of wind forces the aeroplane down so quickly that the pilot is lifted off his seat. In such cases the petrol will take the position shown in Fig. 45. It also occurs, but for a much longer period of time, when the craft is flown upside down. The float action is then reversed and the needle valve is held open as shown by Fig. 46. Although the fuel is forced to the top of the float chamber, the outlet to the metering system is not uncovered. If the engine is fitted with a fuel pump which is supplied with petrol in the inverted position, the fuel-line pressure is exerted upon the metering system, and an excess amount of fuel may be supplied to the engine. This excess is prevented in some designs by the use of a check valve incorporated in the needle-valve seat, as shown by Fig. 40. Such carburettors function in the inverted position, so the engine will continue to run at full throttle. The design of some of the older models is such that the needle valve is closed in inverted flight and thus cuts off the supply of fuel to the engine.

"In older aeroplane carburettor practice, the carburettor barrel and fuel-discharge nozzles were located ahead of or behind the float chamber. With such an arrangement, when standing with tail down or diving at a steep angle, the main jet was considerably above or below the fuel level. When above, there was a tendency for the fuel to be unduly lean; when below, there was a tendency for the fuel to leak out. In the new Stromberg carburettors the fuel discharge nozzles are located in line laterally with the centre of the float, with the result that the fuel flow is not disturbed in any normal flying position.

"In many carburettors two floats are used, both attached to the same lever and float-needle valve, one ahead of the one to the rear of the fuel-discharge jet. As the carburettor is inclined, the float level rises on one float and goes down on the other, but its position with reference to the discharge nozzle is not changed."

THE STROMBERG NA-R9A CARBURETTOR

THE Stromberg NA-R9A carburettor is a single-barrel updraught carburettor used on aeroplane engines having ratings between 300 and 400 horse-power depending on the supercharger ratio. This model has a single-hinge type float, an accelerating pump, needle-valve type economiser, and needle-valve type mixture control.

Installation

The carburettor should be mounted on the engine so that the float chamber is at the side with the fuel inlet to the rear. The fuel inlet is a $\frac{3}{8}$-in. pipe tap connection located at the top of the fuel strainer boss. A $\frac{1}{8}$-in. pipe tap primer connection is located in a boss at the side of the fuel inlet.

The throttle and mixture-control levers are adjustable radially to any position. The throttle lever, having 70° travel, requires a control-rod movement of $2\frac{9}{32}$ in. The mixture-control lever, having 75° to 80° travel, requires a control-rod movement of about $2\frac{7}{16}$ in.

This model may be used with either a gravity-feed or pressure-feed fuel system, depending on the float-needle valve and seat. When the gravity-feed fuel system has less than a 97-in. fuel head, a $\frac{5}{16}$-in. needle-valve seat is used and the float level set using 1 lb. pressure. Carburettors equipped with these seats (commonly referred to as "gravity-type seat") at the factory have a tag "Gravity Feed" attached to them. Carburettors not so tagged should be used with a fuel pump and a pressure at the carburettor of 3 lb. per square inch maintained, or a gravity system having a minimum fuel head of 97 in. The fuel level should be checked under the condition encountered in service as regards the fuel used and the fuel pressure or head at the carburettor. The pressure-type seat size is 0·196 in. (No. 9 drill). If for any reason the seat is changed in service from one type to the other, the gravity-feed tag should either be removed or added as the case may be.

Adjustment

The main and economiser metering jets used in the carburettor are of the fixed orifice type, and their size, as well as the remainder of the carburettor specification, have been determined by test work by the manufacturers, so that no adjustment for cruising and full-throttle speeds is required. An idle adjustment is provided to take care of slight production

variations in the carburettors and engines. A small lever at the rear of the throttle-valve body may be moved to control the richness of the mixture at idling speeds. A quadrant behind this lever indicates, by the letters R and L, the direction to move it to obtain a rich or lean mixture, and also acts as a locking device to hold the lever in position. A throttle stop is provided on the throttle shaft next to the throttle control lever, which should be adjusted to obtain the desired engine speed. Both the throttle stop and the idle adjustment should be set with the engine hot to obtain the proper idling speed and smooth operation.

Servicing

Once the carburettor is properly installed and the idle adjustments made, very little attention is required in service. A fuel strainer is located at the left side of the carburettor, and may be removed by the removal of the large square-head nut at the bottom of the carburettor. A small square-head nut is provided as a drain in the bottom of the float chamber. The strainer and drain nut should be removed frequently to get rid of any dirt or water which may have accumulated in the strainer chamber or the float chamber. The entire carburettor should also be inspected to see that all parts are tight and made safe, and a small quantity of oil put on the pump-operating mechanism.

Overhaul

The carburettor should be dismantled for cleaning and inspection each time the engine is given an overhaul. After the carburettor has been removed from the engine and the hot spot and air intake or heater taken off, the halves of the carburettor may be separated by the removal of the filister head screws at the parting surface and the venturi setscrew. The economiser needle, mixture-control needle, pump sleeve, and venturi are held in the throttle body. The pump sleeve should be slipped off the operating stem as soon as the halves are separated, as it is a brass stamping, and is easily bent if allowed to drop on the floor or bench. If it is necessary to remove the venturi, it will have to be driven out, using a wooden plug. All parts in the bodies, with the possible exception of the idle discharge jet assemblies, should be removed to enable a thorough cleaning and inspection.

Cleaning and Inspection

The bodies and all parts should be thoroughly cleaned in petrol, and all passages blown out with compressed air. All variable parts should be checked to see that their sizes are in accordance with the latest carburettor specification sheet for the engine. Inspect all moving parts to see that they do not have excessive clearance.

Reassembly

All headless screw plugs below the fuel level should be assembled with shellac, being careful not to get it on the end of the plug where it will come off and be carried by the gas into one of the metering orifices. Headless screw plugs above the fuel level and all other threaded parts screwed into the bodies should have a compound of graphite and castor oil put on the threads.

It is recommended that in replacing a float-needle valve or a needle-valve seat these two assemblies be replaced at the same time, as it is very difficult to fit a new needle to an old seat or a new seat to an old needle. The float level should be $\frac{3}{4}$ in. below the parting surface and is dependent upon the thickness of the gasket under the needle-valve seat. The level should be checked under the conditions encountered in service as regards the fuel used and the fuel pressure or head at the carburettor. Those carburettors having a $\frac{5}{16}$-in. needle seat or gravity type, which is that one used with a gravity feed system having less than a 97-in. fuel head, should have the level set using 1 lb. pressure (39 in. petrol at 0·710 gr.) at the carburettor. Those carburettors having a 0·196-in. needle seat or pressure type, which is that one used with a gravity feed system having more than a 97-in. fuel head or a fuel pump, should have the level set using 3 lb. pressure (117 in. petrol at 0·710 gr.). If, after assembling, the level is not correct, remove the needle-valve seat and put in thicker gaskets to lower the level or thinner gaskets to raise it. A change in gasket thickness of $\frac{1}{64}$ in. will change the level approximately $\frac{5}{64}$ in.

When any parts of the mixture-control system are replaced, care should be taken to see that they are assembled correctly. As previously explained, the needle valve is operated by an eccentric pin which is a part of the mixture control stem assembly. The mixture-control stop is pinned to this same stem, and it is important that the stop be located on it at the proper angle with the eccentric pin. This may be done by placing the mixture-control stem, without the stem nut, spring, and packing, in the throttle-valve body, with the eccentric pin away from the pump mechanism and turning it until the distance from the parting flange surface to the pin is $\frac{9}{16}$ in. With the stem held in this position, place the mixture-control stop against the shoulder of the stem with the stop against the stop in the body (full rich position), and drill through the stop and stem. Then assemble the spring, packing, and nut on the stem, press the stop on against the nut, and pin in place.

The mixture-control needle is screwed into the needle holder, and these parts should be so adjusted that a needle-valve travel of $\frac{17}{64}$ in. + 0·000 in. − $\frac{1}{64}$ in. and a lever travel of 75° to 80° is obtained. An approximate adjustment may be obtained before assembling the needle valve in the upper half by setting the bottom of the holder slot $\frac{11}{32}$ in. from the main-body parting surface with the needle valve held down against the needle-valve seat. When this preliminary adjustment has been made, assemble

the two halves together and determine if the needle has $\frac{17}{64}$ in. $+$ 0·000 in. $-$ $\frac{1}{64}$ in. travel. The needle travel may be checked by removing the jet and plug below the needle. When in the full-lean position, the needle stops against the needle-valve seat; when in the full rich position, the stop strikes the stop lug. When the proper adjustment has been made, pin the needle to prevent its changing in service. In assembling the needle in the carburettor, the slot in the holder should be placed with the opening away from the pump mechanism.

The position of the economiser-needle adjusting nut determines the engine speed at which the needle is lifted off its seat, and it is therefore important that this be set correctly in order that the engine will not be operating on too lean a mixture near full throttle or too rich a mixture at cruising speeds. The throttle opening at which the economiser should come in is given on the specification sheet as the economiser setting. This is the travel in degrees of the throttle valve from closed position to that point where the forked lever on the throttle shaft engages the economiser needle adjusting nut. To find the angle which the valve makes with the horizontal flange surface when the economiser comes in, add the throttle-valve angle (given on the specification sheet) to the economiser setting. If the economiser setting is 33° and the throttle-valve angle is 20°, the angle which the throttle valve will make with the horizontal flange surface when the forked lever engages the economiser needle is 53°. When the final adjustment is made, use another nut to lock or jam the adjusting nut, being careful, however, not to change the setting.

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